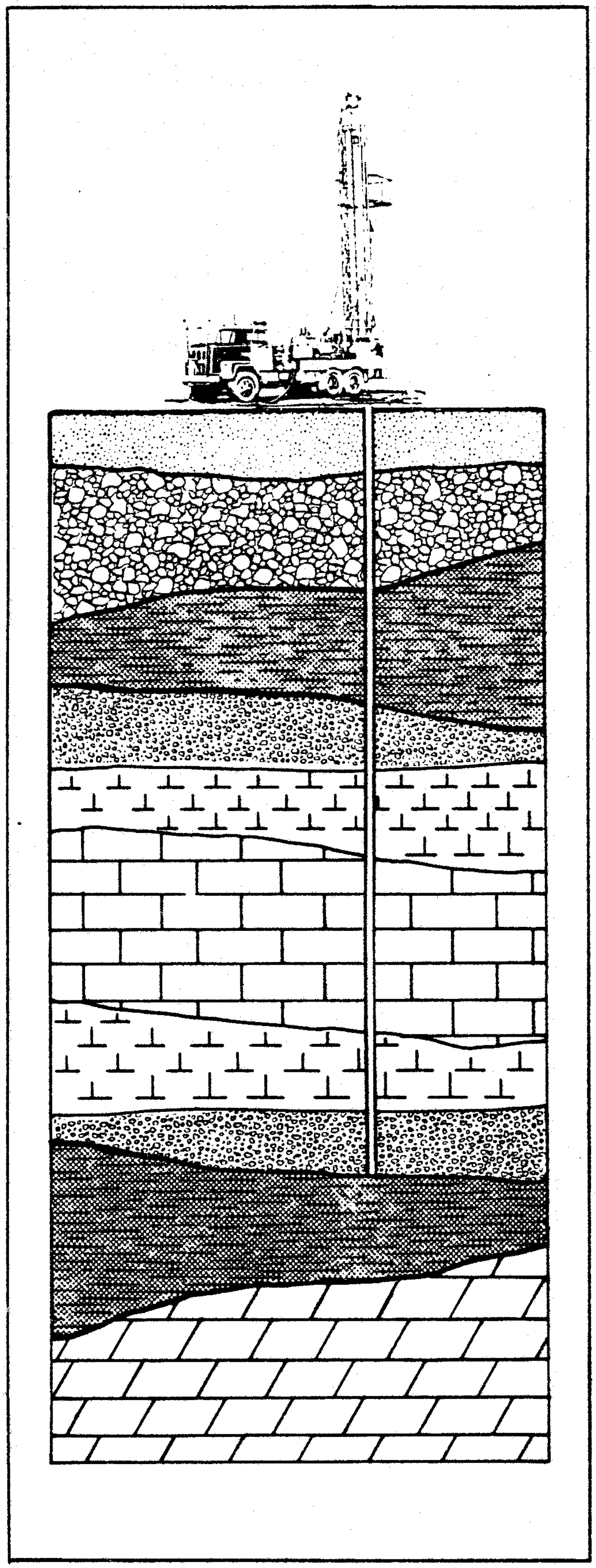


ROCKINGHAM COUNTY GROUNDWATER

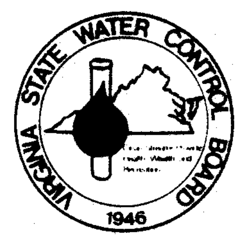
PRESENT CONDITIONS

AND PROSPECTS

by

Kenneth R. Hinkle

R. McChesney Sterrett



COMMONWEALTH OF VIRGINIA

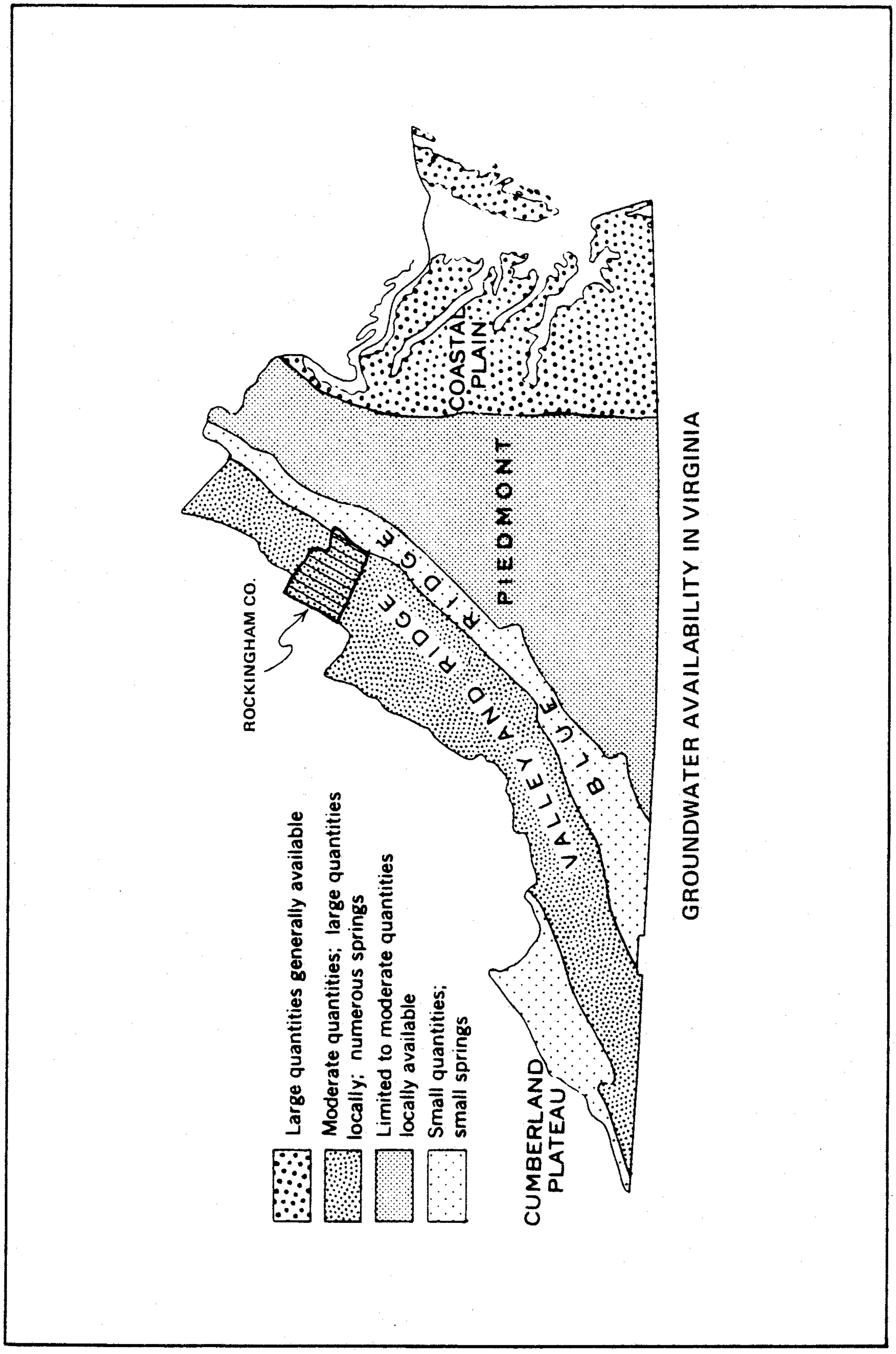
STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 300

July 1976



Source: Virginia State Water Control Board – BWCM

Frontispiece

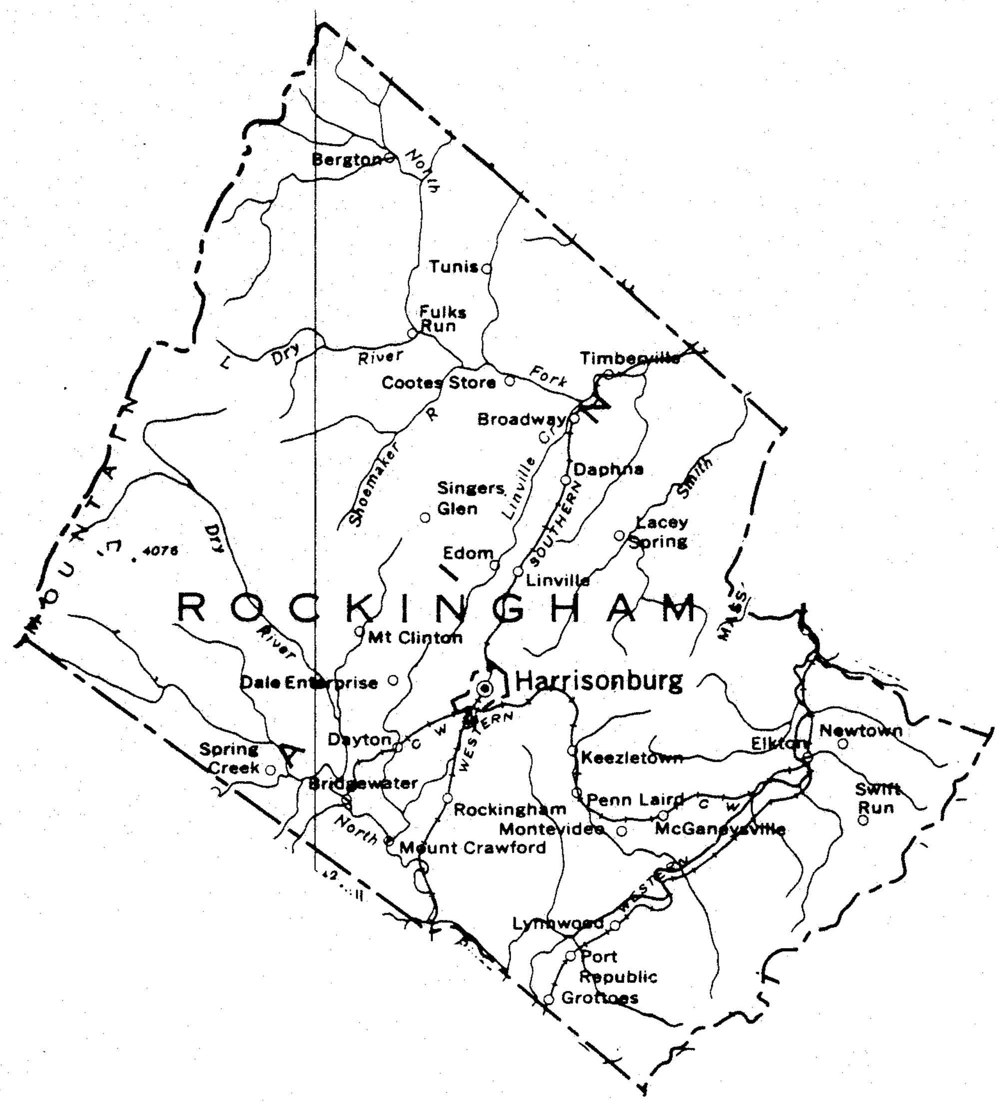
ERRATA

Rockingham County Groundwater, Present Conditions and Prospects
Planning Bulletin 300

PAGE	PARAGRAPH	LINE	ERROR	CORRECTION
Title Page	Map		McGaneysville	McGaheysville
Foreword	2	3	mind	minds
17	Plate 2A		deletion of name	Add: Flagpole Knob at elevation 4381, lower left-hand corner
17	Plate 2A		MASSANUETTEN MNT.	MASSANUTTEN MTN.
17	Plate 2D		Valley Soils bracket encompasses 1 through 4	Valley Soils bracket should encompass 2 and 3 only
30	Plate 5	Title	GROUND-WATER	GROUNDWATER
33	Plate 6		MASSANUETTEN SYNCLINE	MASSANUTTEN SYNCLINE
33	Plate 6	Legend, line 2 under O€	Fiar	Fair
33	Plate 6		GREEN	GREENE
35	Plate 7	Title	COUNY	COUNTY
35	Plate 7	Legend, Line 2	SILRUIAN	SILURIAN
35	Plate 7	Section A-A' Section B-B'	Incorrect symbol	Extreme western formation on both sections should be rather than
36	2	12	ages	Ages
54	2	7	has	have
56	Table 3	Footnote, line 2	particulr	particular
66	1	4	is	are
71	Table 7	Title	GROUND-WATER	GROUNDWATER
75	Plate 10	Legend, line 4	●ABOVE-500	●ABOVE 500
End Flap	Plate 12	Title, line 2	P. O. Box 1143	P. O. Box 11143

ROCKINGHAM COUNTY GROUNDWATER

Present Conditions and Prospects



by

Kenneth R. Hinkle
R. McChesney Sterrett

VALLEY REGIONAL OFFICE

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

Planning Bulletin 300

July 1976

FOREWORD

This report is part of a series intended to cover the entire State, and to provide private citizens, groundwater users, developers, investors, well drilling contractors, consultants and professionals, and government officials with as complete a picture as possible of the groundwater situation, including prospects, as it exists in each of the counties of Virginia.

On the basis of this report, prospective groundwater users and anyone else interested in the development and protection of that invaluable resource that is groundwater can make up their mind and call a consulting hydrogeologist to handle their specific groundwater problem, while the State Water Control Board remains at the public's service for general information and governmental action.

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ROCKINGHAM COUNTY GROUNDWATER

Present Conditions and Prospects

by

Kenneth R. Hinkle and R. McChesney Sterrett

ABSTRACT

In Rockingham County, bounded by the Blue Ridge on the southeast and the Alleghany Mountains on the northwest, the geologic formations occur in northeast trending belts paralleling the ridges and valleys. Sedimentary rocks comprised mainly of shale and sandstone make up the mountainous western portion of the County and also form Massanutten Mountain in the east central portion. The central valley is underlain by limestone and dolomite with a few broad belts of shale. The Blue Ridge portion of the County is comprised mainly of igneous and metamorphic rocks.

Three major hydrogeologic areas have been identified: the Blue Ridge; the central valley; and the area west of Little North Mountain. Maximum groundwater potential is available from the carbonate formations underlying the thick terrace and flood plain deposits bordering the South Fork of the Shenandoah River in the central valley. Carbonate formations elsewhere in the valley offer fair to good potential depending upon local rock characteristics and topography. The Martinsburg shale formation is an important

domestic water supplier in the valley but cannot reliably supply large commercial, public or industrial users. The Blue Ridge and the area west of Little North Mountain offer very poor groundwater potential; only small domestic supplies may be developed in these areas.

Groundwater quality is generally good but varies according to rock type. Hardness is the most common problem and is confined mainly to groundwater from the carbonate rocks and the Martinsburg formation. High iron concentrations are common in groundwater from the shale and sandstone formations west of Little North Mountain. Groundwater in a narrow corridor paralleling U.S. Route 11 and extending from Mt. Crawford to Harrisonburg exhibits an unusual quality relative to the rest of the County: extremely high hardness and high concentrations of iron, sulfate, chloride and nitrate have been detected in this area, though no health hazards are known. In the Blue Ridge, groundwater is very low in dissolved mineral matter and generally of good quality.

Groundwater development has been relatively insignificant in the County. Present development can probably be doubled without adverse effects as long as responsible groundwater management programs are observed. Approximately eight million gallons per day have been withdrawn over the past 20 years from an industrial well field developed in the alluvial deposits along the South Fork of the Shenandoah River. This area offers the best potential for future groundwater development in Rockingham County and probably can support heavy withdrawals over long periods of time.

CHAPTER I

INTRODUCTION

Background

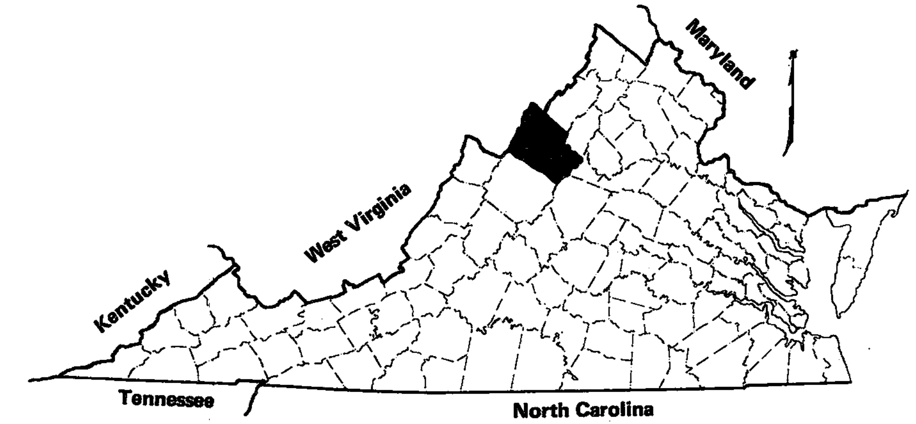
Rockingham County is located in the northwest portion of the State (Plate 1), bounded on the west by West Virginia (Hardy and Pendleton Counties). Virginia counties forming the other boundaries are: Augusta on the south, Albemarle and Greene on the east, and Page and Shenandoah on the north.

Situated in the Shenandoah Valley and named for the Marquis of Rockingham, a British statesman, the County was formed in 1777 from Augusta County. It is the third largest in the State and covers 871 square miles (557,440 acres) including the city of Harrisonburg, the only independent city in the County.

According to 1972 projections, the population was approximately 51,400 for the County and approximately 15,500 for Harrisonburg. For the years 1985 and 2000, respectively, the population is projected to be 64,000 and 80,400 for the County, and 16,700 and 17,900 for Harrisonburg.

Agriculture and manufacturing are the prime sources of revenue and together account for 40 percent of the combined county/city work force of 37,000. Noted as one of the nation's largest producers of poultry products, Rockingham County boasts some of the most modern food processing plants in the

INDEX MAP OF ROCKINGHAM COUNTY



POPULATION (1972 Projections)
County: 51,400
Harrisonburg: 15,500

AREA
Acres: 557,440
Square Miles: 871

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: Virginia State Water Control Board – VRO

PLATE NO. 1

world. Travel and tourism are also important economic factors with activities such as hiking, camping, skiing, boating, swimming, fishing, hunting and sight-seeing offered to visitors.

Present groundwater and surface water supplies appear to be adequate, and no major problems are known to exist in the County. Future groundwater demand can be met without problems based on the present rate of development. The resource, however, is not evenly distributed, and certain areas offer far greater groundwater potential than others due to diversified geology and topography. No serious quality problems are known, but groundwater in limestone terrains is susceptible to pollution.

Purpose and Scope of Report

The purpose of this report is to acquaint the public with groundwater conditions in Rockingham County. In addition to providing some general information about the County, the report is a compilation of previous geologic and hydrologic investigations carried out under the auspices of the State Water Control Board, the former Division of Water Resources, and other State agencies. By discussing groundwater availability, quality and development, the report is intended to serve as a reference to local government, private citizens, developers, well drilling contractors, consultants and anyone else desirous of information relative to utilizing and protecting the groundwater resources of the County. A

Glossary and Bibliography are provided at the end of this report for the convenience and comprehension of the reader.

Methods of Investigation

Most of the general background and geologic information appearing in this report is a summary of previous work. Some of the information on water well construction and groundwater quality has been obtained from other State agencies, although the bulk of it has been collected by the State Water Control Board.

Much of the previously unpublished information on individual well construction data and quality analyses has been collected as a result of the "Groundwater Act of 1973". This Act requires that drilling contractors submit a Water Well Completion Report (Form GW-2) for all wells drilled, and that owners of industrial and public water supplies submit quarterly reports (Form GW-6, Groundwater Pumpage and Use) detailing groundwater withdrawal. In addition, the Board requires that drillers submit drill cutting samples collected at 10-foot intervals on all public and industrial supply water wells and those wells which are drilled to unusual depths or are located in areas deemed deficient in geologic information.

A concentrated effort has been made over the past year to gather information relating to groundwater quality trends in Rockingham County. In addition to specific sampling areas, groundwater quality information is obtained from regular monthly sampling runs made by the Board's Valley Regional Office. Domestic supplies are generally sampled although some small industrial and commercial supplies are checked occasionally.

Another source of quality information is the Pollution Response Program (PReP), maintained by the Board for the sole purpose of responding to citizen reports of water pollution of any type. This includes pollution of both groundwater and surface water by accidental or intentional spills of hazardous chemicals, oil, gasoline, refuse and industrial wastes.

All well and groundwater quality information cited in this report is on permanent file at the Board's Headquarters Office in Richmond and the Valley Regional Office in Bridgewater. These data are computerized for storage and retrieval and were used to compile the summaries contained in Appendices B and C.

Previous Investigations

A number of reports have been published on the geology and groundwater resources of Rockingham County. The most recent and comprehensive geologic report was published by the Virginia Division of Mineral Resources in 1960. The report, Geology and Mineral Resources of Rockingham County (Bulletin 76), was written by William B. Brent and has been drawn upon heavily in preparing the geology part of this report.

Groundwater reports include works by R. C. Cady, R. H. DeKay, and an unpublished thesis by R. B. Leonard entitled Ground-Water Geology Along the Northwest Foot of the Blue Ridge Between Arnold Valley and Elkton, Virginia. Cady's report, Ground-Water Resources of the Shenandoah Valley, Virginia (Bulletin 45 of the Virginia Geological Survey, 1936), is quite comprehensive and is the only major groundwater report to incorporate virtually all of the County. In Development of Ground-Water Supplies in Shenandoah National Park, Virginia (Mineral Resources Report 10, Virginia Division of Mineral Resources, 1972), DeKay touches lightly upon some of the groundwater resources of the Blue Ridge area of the County. Frank Reeves discussed another aspect of the subsurface water resources in his 1932 report, Thermal Springs of Virginia (Bulletin 36, Virginia Geological Survey). The Virginia Division of Water Resources report on the Potomac-Shenandoah River Basin (Volumes I and III, 1968-69) included Rockingham County as did Trainer and Watkin's report entitled Geohydrologic Reconnaissance of the Upper Potomac River (U.S. Geological Survey Water Supply Paper 2035), published in 1975.

Water Well Numbering System

Water Well Completion Reports are assigned a unique number by which that well is thereafter identified. Water quality and withdrawal data for the well are also identified by that number.

Each Virginia county is assigned a three-digit county code, the code for Rockingham County being 182. Within each county wells are numbered sequentially and chronologically, with few exceptions. For example, a report received on a particular day might be numbered 182-16, while a report received the following day would be 182-17. It is unfortunate that owners, particularly industries, which have multiple wells cannot have all of their wells numbered consecutively. All wells are assigned numbers as they are received and therefore appear at random throughout the summary in Appendix B.

Wells appearing in this report will be designated without repeating the county code each time. Numbers will be enclosed in parenthesis; for example: (6). When it is necessary to contact the Board about a particular well, it is advisable to refer to the owner (or location if more descriptive) and its well number. Example: Jordan Hatchery #2, Well No. 182-6.

Acknowledgements

Water well contractors have been the principal source of data used in this report, particularly by filing Water Well Completion Reports, and their cooperation is greatly appreciated. Gary F. Burner of Burner Well Drilling provided many of the reports and was always willing to supply any additional information available. Other drilling contractors supplying well data were Caldwell Well Drilling, Earman Well Drilling, John

Hilbert, Sydnor Hydrodynamics and Virginia Well Drilling.

Several State agencies have been instrumental in providing a variety of data used in this report. The Virginia Division of Mineral Resources provided geologic information through reports and verbal contacts, and the Virginia State Department of Health provided quality data on public water supplies. The Soil Conservation Service graciously supplied soil maps and charts, and special thanks are extended to John Hockman and Charles Neal of the Rockingham County Soil Survey for soils advice. The Water Resources Research Center at Virginia Polytechnic Institute and State University in Blacksburg provided hydrologic and climatic information.

Many citizens of Rockingham County have been most helpful in furnishing information, and it is they who have made possible the collection of most of our groundwater quality samples. Many of these private well owners also provided us with considerable information on well construction.

CHAPTER II

PHYSICAL SETTING

Physiography

Rockingham County is situated almost entirely within the Valley and Ridge Physiographic Province which is characterized by alternating ridges and valleys trending in a northeast-southwest direction. The extreme southeastern part of the County is in the mountainous Blue Ridge Physiographic Province. The Alleghany Mountains and the Blue Ridge form the western and eastern County borders, respectively, while the Shenandoah Valley lies between these two mountain ranges, spanning nearly 22 miles at its widest point.

Elevation ranges vary widely in the County (Plate 2). The highest point is Flagpole Knob at 4,381 feet above sea level, seven miles west of Rawley Springs and one and one-quarter miles east of the West Virginia line. The lowest point is approximately 900 feet above sea level where the South Fork of the Shenandoah River flows out of Rockingham County into Page County about five miles north of Elkton.

Massanutten Mountain is the most notable of several prominent landforms in the County. Rising 1,800 feet above the valley floor, this unique double ridge extends about 10 miles into the County from the northeast and terminates in a spectacular peak near McGaheysville. The Mountain is about 45 miles long with

PHYSICAL CHARACTERISTICS OF ROCKINGHAM COUNTY

Source: Virginia State Water Control Board – VRO

PLATE NO. 2

the northern terminus at Strasburg in Shenandoah County. Near the southern peak is a feature known as "The Kettle", a scooped-out bowl area bounded by the eastern and western ridges and the peak proper.

Mole Hill is a volcanic plug located about four miles west of Harrisonburg which rises abruptly out of the valley floor to a height of 500 feet. It is regarded as one of the most outstanding igneous rock occurrences in the Appalachian Valley area of the State.

Caves and caverns are abundant throughout the County (Plate 2). According to Douglas (1963), 100 caves are known, ranking this County third among all others in the State. This includes two commercial caves, Endless Caverns and Massanutten Caverns. An abundance of sinkholes, almost exclusively found in limestone regions, indicates the area is riddled with subsurface solution channels and caves, typical features of karst terrains.

Drainage

Rockingham County is located entirely within the upper Potomac-Shenandoah River Basin. Extending from Highland County in the west to the Chesapeake Bay in the east, the Basin covers 5,706 square miles in Virginia alone.

Three major rivers drain the County (Plate 2). The North River drains the southern and southwestern parts and joins the Middle River at the Augusta County line, one mile west of

Grottoes. Middle River in turn joins with the South River at Port Republic to form the headwaters of the South Fork of the Shenandoah River. From there it flows northeastward following the western foothills of the Blue Ridge, leaving Rockingham County approximately five miles north of Elkton. The River's course is marked by a mile-wide flood plain and is bordered by gravel deposits up to 100 feet thick in some places. The northwest and northern parts of the County are drained by the North Fork of the Shenandoah River which flows out of the County approximately four miles northeast of Timberville.

Climate

Mild winters and warm, humid summers characterize the climate of the study area. The two major controlling factors are the mountainous nature of the area and the wide range in elevation.

According to Crockett (1972), the average annual temperature for the County is approximately 54^{o} F. Extremes have been reported as high as 101^{o}F in July 1954 and as low as -16^{o}F in January 1953. July and August are the warmest months while December and January are the coldest. Average annual precipitation is approximately 35 inches with rainfall the dominant precipitation factor. Summer rainfall is provided principally by showers and thunderstorms, the latter occurring on an average of 40 days. The greatest precipitation generally occurs in July and August. Although the average snowfall figure is approximately 26 inches, measurements in the last 17 years have varied from three inches to 59 inches.

Table 1 lists temperature and precipitation data from the two non-recording weather stations maintained by the National Weather Service.

TABLE 1

1975 DATA RECORDED AT
ROCKINGHAM COUNTY WEATHER STATIONS

Month	Average Temperature (Degrees Fahrenheit) Dale Enterprise	Timberville	Total Precipitation (Inches) Dale Enterprise	Timberville
January	35.3	35.8	2.03	2.41
February	37.0	37.3	2.88	2.41
March	40.7	41.7	5.07	5.58
April	49.1	49.9	1.26	1.54
May	64.7	65.6	4.35	1.94
June	68.5	71.4	3.46	4.32
July	71.0	73.1	4.84	4.45
August	72.0	74.6	5.12	3.21
September	61.5	63.5	5.84	6.97
October	56.7	57.0	2.68	1.71
November	48.3	47.8	2.09	1.62
December	35.7	35.7	2.71	2.48
	53.4	54.5	42.33	38.64
1948-1973	53.7	53.6	34.62	36.26

Source: National Oceanic and Atmospheric Administration and Virginia Water Resources Research Center

Soils and Vegetation

Rockingham County soils can be grouped into three major associations: mountainous soils, valley soils derived from carbonate rock and from shale and shaly limestone, and alluvial soils.

As evidenced by Plate 2 approximately 50 percent of the County is covered by mountainous soils. These soils are fairly shallow in the west but much deeper in the Blue Ridge areas and the Massanutten Mountain sector. All soil types in these highland areas are well drained, particularly on the steep western slopes near the base of the Blue Ridge, and contribute very little recharge to groundwater.

The Valley soils comprise the bulk of the remaining area and are derived from the carbonate rock, shale and shaly limestone which ribbon the valley floor in a general north-south trend. These lowland soils are well drained, 20-50 inches deep on slopes and deeper in the low-lying areas, and offer favorable conditions for groundwater recharge. Numerous rock outcrops are common.

Alluvial and colluvial soils occupy the valley floor along streams and rivers. Soils common to these drainage-ways are moderately well to well drained and are generally quite thick. Terraced flood plains are common and may be flat or gently sloped. These soils foster increased groundwater infiltration due to their permeability and proximity to major rivers.

Vegetation consists of forest lands and agricultural areas, the latter accounting for the major portion of the valley where grazing and cropland predominate. Over half of the County's

557,440 acres are forested; 138,169 acres are included in the George Washington National Forest in the western part of the County. Most forests are the oak-hickory type with substantial tracts in the western half covered by several pine species and mixed hardwoods. Such major forest areas provide large watersheds to replenish and maintain both surface water and groundwater.

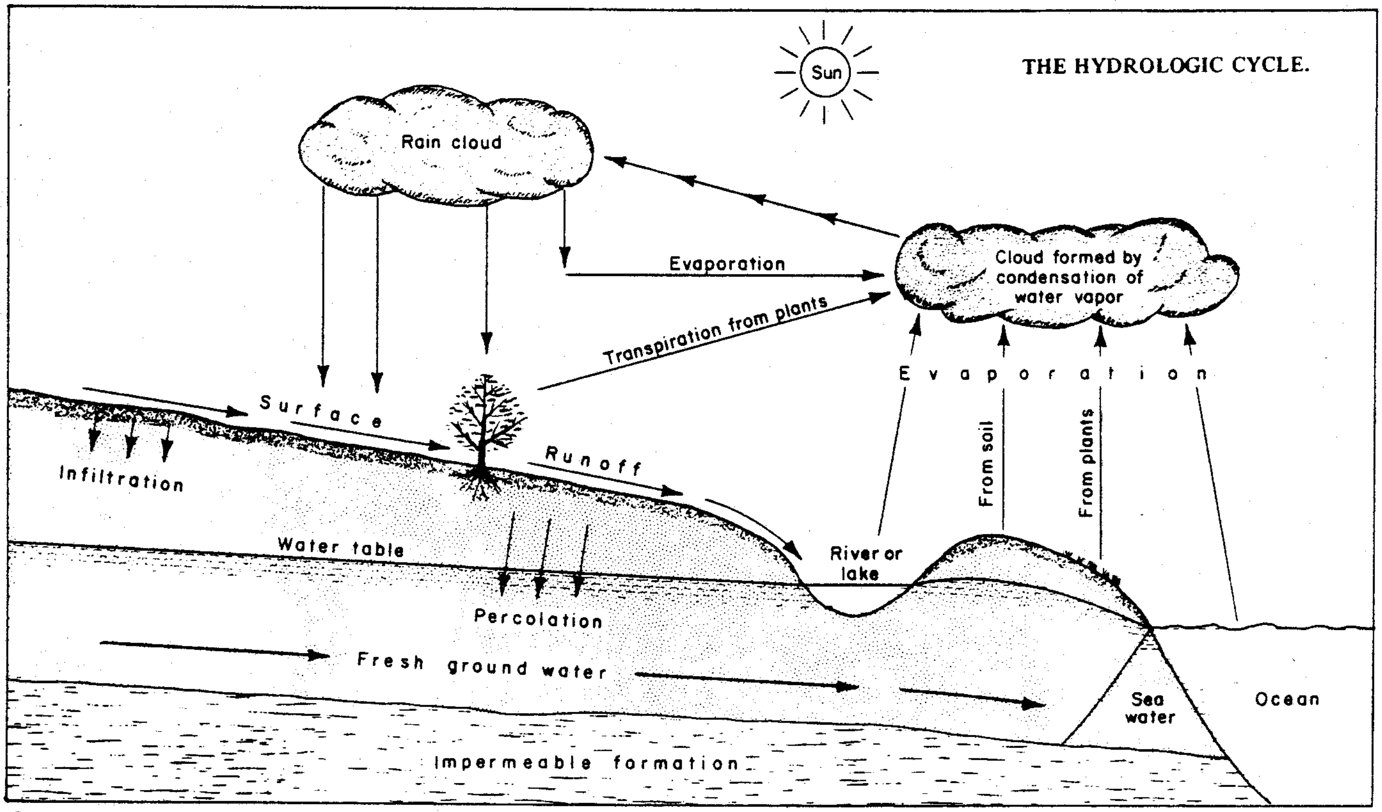
CHAPTER III

HYDROGEOLOGY

Geology and Groundwater

The close relationship between geology and the occurrence, distribution, availability and quality of groundwater makes geologic information a prerequisite to understanding the hydrogeology of an area. Topography, rock type and geologic structure are principal factors which govern the storage, transmission, yield, quality and utilization possibilities of groundwater. Other elements influencing groundwater include soil, vegetation, temperature and certain works of man. Overriding most of these factors are quantity, intensity, frequency, duration and distribution of precipitation. The hydrologic cycle (Plate 3) explains the circulation of water among the oceans, air, land surface and underground.

Topography is a significant factor influencing groundwater conditions. As a general rule, low-lying areas near hills and mountainous regions should be considered as having greater groundwater potential than the higher elevations because runoff from slopes results in increased infiltration in valleys. Pervious soils, cultivated land and dense vegetation allow greater infiltration than do clayey and barren lands which are conducive to higher rates of runoff. High temperature



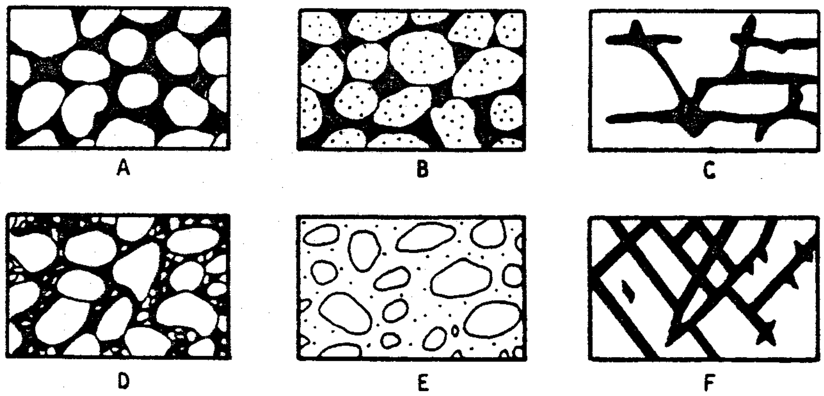
Source: Gibson and Singer (1971) Plate No. 3

coupled with a high degree of evaporation negatively affects groundwater recharge. In urban areas, runoff increases and infiltration diminishes due to the impermeable expanse created by paved areas and buildings.

Different types of rock vary considerably in their ability to absorb, store, and yield water. Except for the Blue Ridge, Rockingham County is underlain by sedimentary rocks which were deposited in ancient seas. These rocks contain water in voids, bedding planes, fractures and solution channels. The predominant rock types in the County are limestone, shale, sandstone, and unconsolidated sand and gravel. For the purpose of this report, limestone, a calcium carbonate, and dolomite, a calcium-magnesium carbonate, will be termed loosely as "carbonates".

Carbonate rocks have highly variable water-bearing properties and are good to poor aquifers. Where joints have been enlarged into solution channels by the dissolving action of water, large volumes of water may be stored and transmitted (Plates 4C and 4F). The solution action can produce openings as large as the greatest caves. It is generally believed that the formation of solution channels in carbonate rocks operates most actively above and immediately below the water table, where the water in the rocks contains a greater charge of carbon dioxide and circulates most vigorously. Carbonate rocks adjacent to major streams have a high potential for recharge and are relatively unaffected by seasonal water table fluctuations. Therefore, limestone and dolomite formations which outcrop near major streams may be very prolific aquifers, whereas those occurring in areas remote from major streams may produce only meager amounts of groundwater.

Shale has relatively high porosity, but permeability is very low. Small to sometimes fair quantities of water may be obtained from pore spaces, joints, bedding planes and shaley partings, but shale generally forms an aquiclude or barrier confining groundwater to underlying aquifers. Clay has hydrologic properties similar to those of shale and is relatively impermeable; i.e., incapable of supplying water to wells.



EXAMPLES OF ROCK POROSITY
(A) Well-sorted sediment - high porosity; (B) Well-sorted sediment consisting of porous pebbles - very high porosity; (C) Porosity resulting from dissolution; (D) Poorly-sorted sediment - low porosity; (E) Well-sorted sediment with intergranular space filled with "cement" - very low porosity; (F) Porosity developed along fractures.

Source: Meinzer (1923) PLATE NO. 4

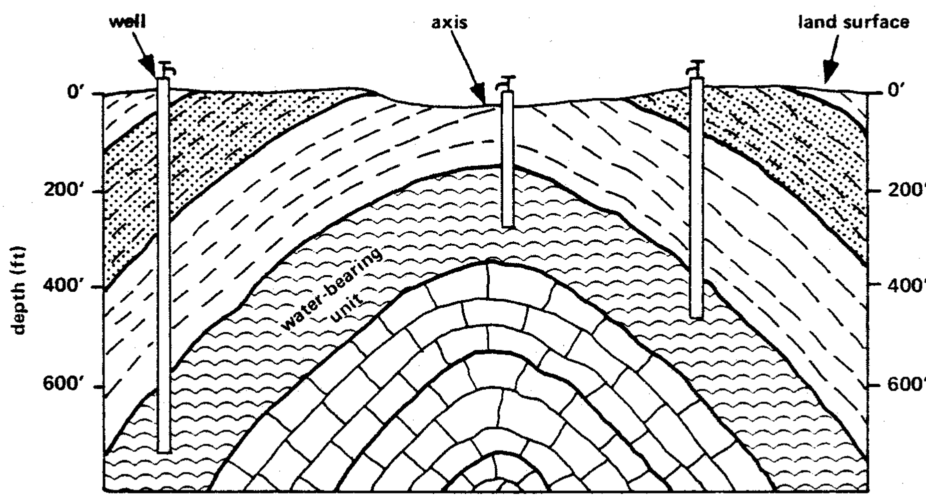
Sandstone contains water in pore spaces which are dependent on sorting, grain size, shape, packing, and most importantly, degree of cementation (Plate 4E). Sandstone cemented with soluble calcite or unstable clay minerals may break down easily and develop high permeability. Some calcareous sandstone formations are excellent aquifers, but a sandstone cemented with silica may have practically no permeability unless fractured.

Unconsolidated sand and gravel in alluvium and terrace deposits are highly porous and permeable and usually occupy areas favorable for groundwater recharge (Plates 4A, 4B and 4D). Sand and gravel beds lying adjacent to, and below the level of, a major stream often yield abundant supplies of groundwater, while sand and gravel in deep strata are also good aquifers. Similar deposits at higher elevations may contain little groundwater.

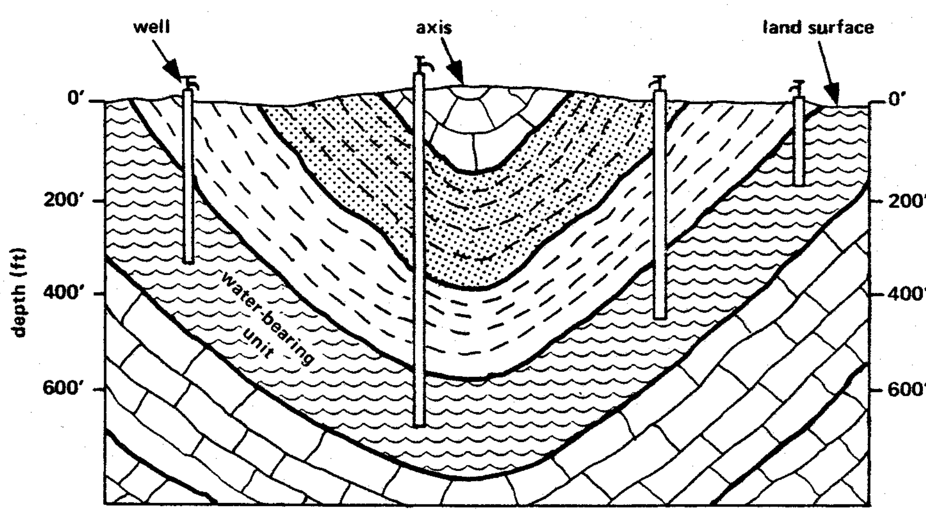
Igneous and metamorphic rocks have very low porosity and permeability. However, small supplies of water are generally available near the surface where weathering has partially decomposed the rocks. Below the weathered zone small quantities of water may occur in fractures and along contacts between different rock types.

Geologic structure may strongly influence the occurrence of groundwater, and this is especially true in certain areas of Rockingham County. Anticlines (up-folds in the rock strata) may bring good water-bearing beds near the surface along their axes and bury them along the flanks (Plate 5A). Similarly, synclines (down-folds in rock beds) may bring water-bearing units near the surface on the flanks or may cause them to descend to great depths along the axis (Plate 5B). The axial portion of a syncline can act as a collection area and, if tapped, may yield significant quantities of water under high pressure. Water may flow under its own pressure to or above the land surface, and when this occurs, the well is termed "artesian". Similarly, excellent groundwater storage potential exists along well-fractured anticlinal axes, but water pressure is generally not sufficient to cause artesian conditions.

STRUCTURAL INFLUENCES IN GROUND-WATER AVAILABILITY



A. An anticline may bring a water-bearing rock bed near the surface at its axis or send it to great depths along its flanks.



B. A syncline may bring a water-bearing rock bed near the surface at its flanks or bury it at its axis.

Source: Virginia State Water Control Board - VRO

PLATE NO. 5

Faults are fracture zones along which there has been displacement of rock masses relative to one another, and they often parallel folding. The associated fracture openings in soluble rocks may be enlarged by the solution action of groundwater, thereby resulting in high well yields. Faulting can also be detrimental to the groundwater potential of an area. Not only can it act as a collection zone for groundwater through the secondary permeability it creates, but it may also serve as a barrier to limit groundwater movement by causing the disappearance of a water-bearing formation.

Joints are fractures along which there has been no appreciable movement. They are favorable to groundwater occurrence, but, like faults and other fractures, tend to become fewer and smaller with depth.

Hydrogeology of Rockingham County

A variety of sedimentary, igneous and metamorphic rocks occur in relatively narrow northeast-trending belts in the County. These rocks have been heavily folded, and two major faults run almost the length of the County. Geologic and groundwater conditions of the area are illustrated on Plates 6 and 7.

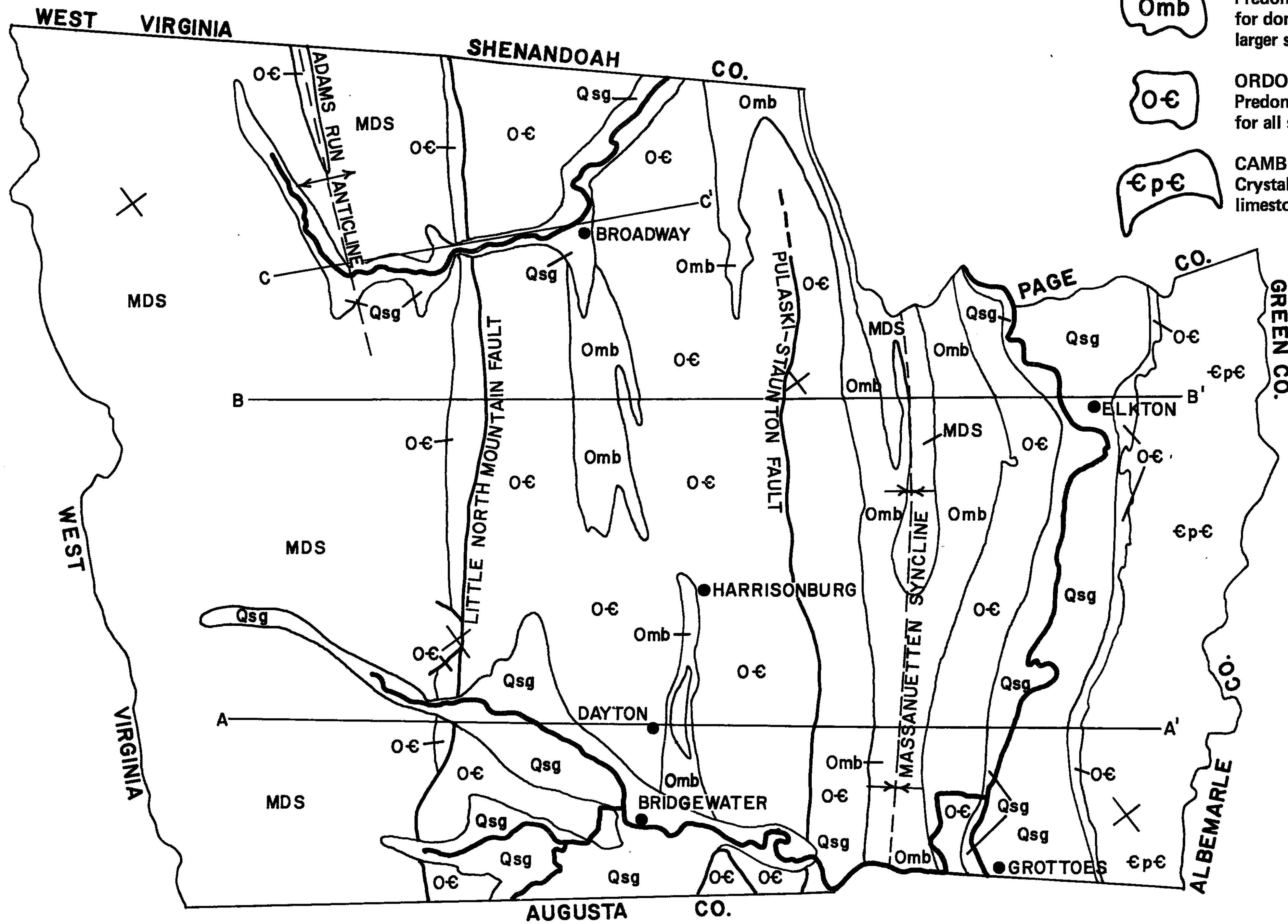
Geologic Setting. The oldest rocks crop out on the Blue Ridge along the eastern boundary of the County and consist of Precambrian igneous and metamorphic types generally considered to be older than 600 million years. Huge masses of granite were

GENERALIZED HYDROGEOLOGIC MAP

ROCKINGHAM COUNTY

Geology modified after William B. Brent

(Bulletin 76, Division of Mineral Resources, 1960)



LEGEND

Qsg — ALLUVIUM, TERRACE AND FLOOD PLAIN DEPOSITS
Chiefly gravel, some sand and clay. Good to excellent water-bearing properties depending upon thickness and lateral extent.

MDS — MISSISSIPPIAN, DEVONIAN AND SILURIAN FORMATIONS
Predominantly shale and sandstone. Poor to fair water producer for domestic supplies.

Omb — MARTINSBURG FORMATION
Predominantly shale. Fair to good well yields for domestic supplies, generally inadequate for larger supplies.

O-Є — ORDOVICIAN AND CAMBRIAN CARBONATE FORMATIONS
Predominantly limestone and dolomite. Fiar to good well yields for all supplies, good to excellent when overlain by alluvial deposits.

Єp-Є — CAMBRIAN AND PRECAMBRIAN BASEMENT FORMATIONS
Crystalline rocks and basal quartzites in east; conglomerate, slate, shale, limestone, sandstone in west; generally very poor water producer.

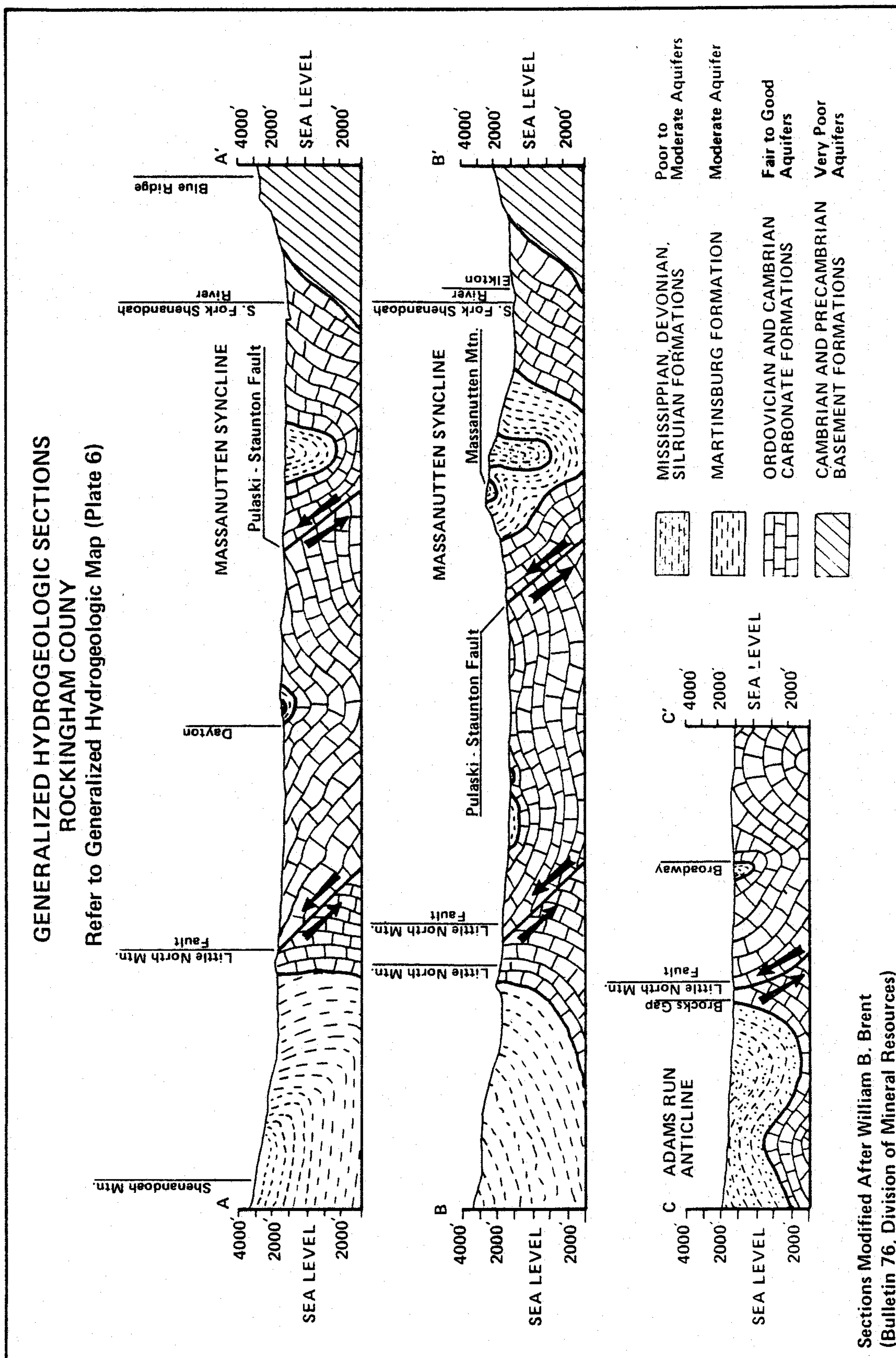
SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: Virginia State Water Control Board — VRO

PLATE NO. 6



Source: Virginia State Water Control Board — VRO

PLATE NO. 7

injected into this area followed by extensive volcanic activity which created lava flows resulting in the present-day greenstone covering much of the Blue Ridge.

The rock formations become younger from southeast to northwest across the Shenandoah Valley, an area mainly underlain by carbonate rocks of Cambrian and Ordovician age (600-425 million years old). These rocks, limestone and dolomite, were deposited when severe deformation caused a long, narrow trough to form in a northeast-southwest direction generally coinciding with the present location of the Appalachian Mountain Range from Alabama to Newfoundland. This huge depression was repeatedly invaded by the sea and served as a depositional site for thousands of feet of sediments over millions of years. During the Silurian, Devonian and Mississippian ages (425-300 million years ago) when uplift caused the sea to retreat, there was rapid erosion resulting in transport of clastic sediments into the depositional trough which later consolidated into the younger shale and sandstone units predominating in Massanutten Mountain and west of Little North Mountain.

Following this long depositional and uplift period the area was again subjected to horizontal forces from the southeast which folded the sedimentary rocks into a series of anticlines and synclines and in some places displaced huge masses of rock for thousands of feet along fault planes. Erosion and terrestrial deposition over the last 300 million years has altered the land surface to its present topography. The more resistant rocks, such as sandstone and quartzite, from the ridges while the less resistant shale and limestone units have been eroded to form the valleys.

A number of younger igneous intrusions emplaced in the older sedimentary rocks are thought to be of Triassic Age (around 200 million years old). The youngest deposits, less than two million years old, are the terraces and flood-plain alluvium which occur in proximity to the major streams.

Geologic Formations and Groundwater Occurrence. The occurrence, lithology, and average thickness of the formations discussed above are detailed in the following paragraphs as a prelude to discussing groundwater occurrence and availability in Rockingham County. Nomenclature is consistent with that used in Bulletin 76, Geology and Mineral Resources of Rockingham County by William B. Brent, published by the Division of Mineral Resources in 1960.

Groundwater conditions vary considerably across Rockingham County due to the diverse geology and topography. The Cambro-Ordovician carbonates are considered the best producers, especially where large streams traverse these formations and where thick deposits of alluvium have accumulated. The Silurian, Devonian, and Mississippian shale and sandstone units along with some of the other carbonate formations have only moderate potential for groundwater, and the igneous and metamorphic rocks forming the Blue Ridge are poor sources.

Precambrian and/or Cambrian rocks (older than 600 million years) designated as the Virginia Blue Ridge Complex form the main core of the Blue Ridge. These rocks consist principally of granodiorite and gneiss and crop out on the crest of the Blue Ridge east of Elkton. Most of the Blue Ridge in Rockingham County is capped by the Catoctin greenstone which was formed by volcanic lava flows during either Precambrian or Cambrian time. All of these rocks are poor groundwater producers.

Cambrian units (600-500 million years old) consist of a thick series of shale and carbonate rock along with lesser units of quartzite and slate. Two important aquifers are the Elbrook dolomite and the Conococheague limestone. The Elbrook underlies most of the South Fork of the Shenandoah River as it makes its course northward from Grottoes to Elkton; two other outcrop areas follow fault zones in the central and western parts of the County. The Conococheague crops out in three narrow northeast-trending belts in the central valley.

The Ordovician carbonates (500-425 million years old) comprise the bulk of the water-bearing formations in the County. The Beekmantown and Edinburg formations are the two principal aquifers, while the Martinsburg shale is a lesser yet significant water-bearing formation. The Beekmantown is basically a dolomite body and covers a large portion of the valley floor. Abundant chert in this formation is responsible for many of the rounded knobs common in the Valley. The Edinburg is a thick limestone and shale unit exposed in several fairly wide belts in the central part of the County. Major population centers, including a large part of Harrisonburg, the towns of Bridgewater, Broadway, Dayton, and part of Timberville, are developed on the Edinburg.

The Martinsburg formation, up to 3000 feet thick, is predominantly a calcareous shale with a few possible limestone beds which may account for the fair groundwater potential available from the unit. It is one of the most persistent formations in the Shenandoah Valley and is widely exposed in Rockingham County. Two large exposures flank each side of the Massanutten Mountain, and several other outcrop belts underlie the lowland areas elsewhere in the central valley.

Silurian rocks (425-405 million years old) consist of relatively thin strata of sandstone, shale and limestone. Silurian sandstone is highly resistant to weathering and is one of the principal ridge-formers in the Appalachian Mountains. Massanutten Mountain is rimmed by one of these sandstone formations. Silurian rocks generally are poor aquifers.

Thick Devonian units (405-345 million years old) crop out west of Little North Mountain and in Massanutten Mountain and are comprised mainly of shale and sandstone with minor amounts of limestone. They offer poor groundwater prospects.

Only one Mississippian formation (345-310 million years old), the Pocono, is present in the County. This massive, light-colored sandstone is prevalent in the Hone Quarry-Rawley Springs area and is a poor aquifer.

Triassic rocks believed to be of 230-180 million years old are basic igneous rocks which have intruded the older sedimentary rocks in several places, the largest of which forms Mole Hill west of Harrisonburg. They offer very little groundwater potential.

Quaternary materials (2 million years old-present) constituting the youngest deposits in the County are the flood-plain alluvium and terrace deposits above the flood plains that represent former levels of the major streams. Notable areas in which these deposits of gravel, sand, silt and clay occur are along the North and South Forks of the Shenandoah and the Dry and North Rivers. These deposits are excellent aquifers.

Geologic Structure. Of the four major structural features present in Rockingham County, the Massanutten Syncline is probably the most important from a hydrogeologic standpoint. The Syncline is basically a very large trough which extends far beyond the County's northern and southern borders and includes Massanutten Mountain. A major formation in the Syncline is the Martinsburg shale which has an east-west span of several miles in some places.

The Adams Run Anticline in the northwest is the other major folded feature. This structure brings older Ordovician rocks to the surface to form Church Mountain, the southern terminus of which is at Fulks Run.

Two major fault zones slice through the County in a northeast-southwest direction. The Pulaski-Staunton fault runs through Massanetta Springs northward just west of Keezletown, while the Little North Mountain fault passes west of Briery Branch and Singer's Glen and extends northward between Brock's Gap and Cootes Store. In both cases older Cambrian rocks have been thrust northwestward over younger Ordovician units.

These structural features directly influence groundwater conditions. The Massanutten Syncline serves as a large runoff collection area to recharge the Martinsburg shale and underlying carbonate formations, and Church Mountain offers steep slopes to provide recharge to the northwest section of the County. Major fracture patterns have been developed in the carbonate formations bordering the major faults, thus facilitating infiltration and groundwater occurrence.

Table 2 summarizes the geologic formations of Rockingham County including their water-bearing properties. Groundwater potential of the various geologic formations underlying the County will be elaborated upon in the next chapter.

TABLE 2

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

ROCKINGHAM COUNTY*

System	Age (Million Years)	Formation	Symbol	Thickness (ft) and Distribution	Lithology	Water-Bearing Properties
Quaternary	2-Present	Alluvium & terrace deposits	Qsg	bordering major streams	Unconsolidated sand, clay, & gravel	Excellent; yields up to 2000 gpm known
Triassic	230-181	Intrusive igneous rocks	Tr	Crest of Blue Ridge; Mole Hill	Dikes, sills & plugs of basic igneous rock	Very Poor
Mississippian	345-310	Pocono	Mp	300+ Shenandoah Mountain	Massive white to gray sandstone with some dark shale	Poor
Devonian	405-345	Hampshire	Dhs	2000 West of Little North Mtn.	Chiefly red sandstone, shale and mudrock	Poor
		Chemung	Dch	2000 West of Little North Mtn.	Gray to greenish silty sandstone and brown to gray shale	Poor
		Brallier shale	Db	1200 West of Little North Mtn.	Greenish to brown shale and fine grained thin-bedded greenish sandstone	Poor
		Millboro and Onondaga shale	Dmo	400-500 West of Little North Mtn., Kettle of Massanutten Mtn.	Fissile black shale, weathers light gray or pinkish	Poor to Fair
		Ridgeley sandstone	Dri	50-150 West of Little North Mtn.; Church Mtn.	Coarse-grained gray to white quartz sandstone	Poor

TABLE 2 CONTINUED

		Helderberg limestone	Dhl	100-400 West of Little North Mtn.;Church Mtn.	Gray limestone, chert, some shale	Poor to Fair
		Cayuga group	Scy	220-600 Church Mtn.; Massanutten Mtn.	Chiefly finely-laminated gray limestone	Poor to Fair
Silurian	425-405	Clinton	Scl	150-500 Church Mtn.	Red sandstone, red and green shale	Poor
		Massanutten sandstone	Sm	500-700 Massanutten Mtn	White quartzite,quartz pebble conglomerate commonly at base	Poor
		Clinch sandstone (Tuscarora quartzite)	Sc	50-200 Church Mtn.	White to gray massive quartz sandstone	Poor
		Juniata	Oj	250 Church Mtn. Little North Mtn.	Red sandstone and red shale	Poor
		Oswego sandstone	Oos	300-600 Little North Mtn.	Thick-bedded greenish to bluish gray dense sandstone	Poor
		Martinsburg shale	Omb	1500-3000 Little North Mtn.	Shale,calcareous and silty in part	Fair to good for domestic supplies only
Ordovician	500-425	Edinburg	Oe	1500 valley floor	Dense,dark-blue to black limestone,black shale commonly at base	Fair;unusual quality parameters typical,mud seams
		Lincolnshire limestone and New Market limestone	Oln	50-150 / 50-200 valley floor	Medium-grained,dark limestone with black chert./Dove-gray compact,pure limestone	Fair / Fair
		Beekmantown	Ob	2000 valley floor	Thick-bedded,gray,medium grained dolomite,some blue limestone, much chert	Fair to good;mud seams common
		Chepultepec limestone	Och	500 valley floor	Blue and gray limestone, some dolomite, some black chert	Fair

TABLE 2 CONTINUED

		Conococheague limestone	Cco	2500 / valley floor	Thick-bedded bluish limestone, some dolomite, thin sandstone beds	Fair to good
		Elbrook dolomite	Ce	2000 / valley floor	Thin and thick-bedded dolomite, limestone, some shale	Good when overlain by alluvium; otherwise fair to good
		Rome	Cr	1700 / valley floor	Red and brown shale, calcareous shale, siltstone, some limestone	Good when overlain by alluvium; otherwise fair
Cambrian	600-500	Shady	Cs	1000 / Base of the Blue Ridge	Dolomite, some limestone, some shale	Good
		Erwin quartzite	Cer	800 / Blue Ridge	Brown sandstone, white, thick-bedded quartzite	Poor
		Hampton	Ch	900 / Blue Ridge	Thin-bedded, dark-gray to greenish siltstone, shale or phyllite at base	Poor
		Weverton	Cw	900-1500 / Blue Ridge	Quartzite, greenish siltstone, shale, phyllite, conglomerate	Poor
		Loudoun	Cl	0-200 / Blue Ridge	Spotted purple or gray slate, some lava flows	Poor
Cambrian or Precambrian	?	Catoctin greenstone	CpCc	0-1000 / Blue Ridge	Altered lava, interlayered sedimentary materials	Poor
		Swift-run	CpCs	0-100 / Blue Ridge	Conglomerate, quartzite, slate	Poor
Precambrian	Older than 600	Virginia Blue Ridge Complex	pCv	Blue Ridge	Granodiorite, gneiss, and other altered rocks	Poor

*Modified after Brent, 1960.

Source: Virginia State Water Control Board - VRO

Groundwater Movement and Storage

While there have been no detailed studies conducted of groundwater movement and storage in Rockingham County, it is recognized that a very close relationship exists between surface water and groundwater. Groundwater movement and storage are influenced by topography, rock type, and geologic structure. and movement is generally in the same direction as surface runoff, only much slower. Movement and storage patterns in three different sectors can be delineated: those in a) alluvial deposits; b) carbonate formations; and c) shale/sandstone units.

Movement. Elevation is the prime factor determining groundwater movement in alluvial deposits. When the water table is at a higher elevation than a stream bed, groundwater will move toward the stream, thus maintaining surface flow during dry periods. During those times of year in late summer and early fall when the water table generally drops, conditions may reverse resulting in seepage of water from the stream into adjacent flood-plain deposits.

Groundwater movement within the thinly-covered carbonate rocks underlying the central portion of the County is more complex. Some of the carbonates are very dense and resistant to the dissolving action of water while others commonly contain abundant solution cavities and provide for rapid movement and abundant storage of groundwater. The unpredictable size, shape, and direction of solution cavities makes groundwater movement very erratic in the carbonates. Where highly-fractured carbonates are exposed at the surface, optimum conditions often exist for surface runoff to enter directly into solution channels. Quite often a single sinkhole serves as a major infiltration point for groundwater recharge. Once water enters solution cavity systems, it behaves much in the same manner as surface streams and may discharge some distance away as a spring. Many of the large springs in Rockingham County (such as Lacey Spring) are believed to originate in this manner. Sometimes an entire stream may disappear in carbonate rocks and emerge as a large spring many miles away, thus giving rise to such names as Sinking Creek or Lost River. However, there are no known examples of this situation in Rockingham County.

Movement in the shale/sandstone areas of the western part of the County is relatively simple. Water infiltrates the rock until it intersects bedding planes and then flows down-dip. Very few fractures are found in shale, so movement patterns are directly controlled by structure.

Storage. Maximum groundwater storage is possible in the alluvial and terrace deposits bordering major streams. These deposits consist mainly of coarse gravels and boulders which provide maximum voids. The most important groundwater storage area in this County is the alluvium bordering the South Fork of the Shenandoah River. Other notable examples are along

Briery Branch and Dry River in the southwest and along the North Fork of the Shenandoah River between Timberville and the Shenandoah County line.

Where the flood-plain deposits overlie carbonate rocks with abundant solution cavities, groundwater conditions are considerably enhanced. Not only do these deposits provide for storage at shallow depths, but deeper wells can often tap abundant supplies stored in the cavernous bedrock.

Storage in carbonate rocks depends, as with movement, on the rocks' resistance to the dissolving action of water. Large solution voids sometimes act as reservoirs, and fractures resulting from structural activity can contain vast amounts of water.

The shale formations as well as most of the sandstone units seldom afford adequate groundwater storage. A possible exception is the Martinsburg shale unit underlying much of the central valley portion of the County. The unit is situated in a syncline which tends to divert and collect groundwater along the structural trough even though the rock composition does not favor significant storage. Shale units west of Little North Mountain, however, have undergone relatively insignificant structural changes and are not considered good for groundwater storage. The absence of large springs and the fact that Dry River sometimes ceases to flow during the late summer months seem to bear this out.

CHAPTER IV

GROUNDWATER POTENTIAL AND DEVELOPMENT

Groundwater Potential

The groundwater potential of an area is the ability of that area to yield groundwater. Potential is a relative guideline determined mainly by rock type, though factors such as topography and geologic structure are also important.

Owing to the diversity and complexity of the hydrogeologic environment, obtaining groundwater in Rockingham County is not a simple matter of putting down a hole as it can be in relatively uniform hydrogeologic areas such as the Coastal Plain of Virginia. Five major hydrogeologic units are delineated on Plate 6: Cambrian and Precambrian basement formations; Ordovician and Cambrian carbonate formations; the Martinsburg formation; Mississippian, Devonian and Silurian formations; and alluvium, terrace and flood plain deposits. On this basis, three major hydrogeologic areas have been defined in the County: the Blue Ridge; the Central Valley; and the area west of Little North Mountain.

Specific water-bearing characteristics of each of these areas is discussed below. The information is based mainly upon well construction and pumpage data presently available.

Blue Ridge Area. Poor groundwater potential characterizes this region. The igneous and metamorphic rocks which make up the Blue Ridge and its environs are typically very dense and contain no pore spaces in which water can collect and move. Water is generally confined to a few small cracks and fractures occurring near the surface where the material may have been subjected to weathering. Fractures that do exist usually are not large enough to supply more than a few gallons per minute. Other factors contributing to the unfavorable conditions for groundwater are the steep slopes resulting in a high rate of runoff and the shallow soil cover reducing the amount of infiltration. However, these factors are secondary; gentle slopes and thick soils would result only in a very limited increase in potential due to the poor porosity and permeability of the rocks in this area.

Central Valley Area. The central valley, the best groundwater potential zone in this County, includes the area between the western toe of the Blue Ridge and the eastern base of Little North Mountain. Although Massanutten Mountain is located within these boundaries, it will be discussed under "Area West of Little North Mountain" due to its hydrogeologic similarity with that sector.

The carbonate formations and the overlying alluvial and terrace deposits along the west toe of the Blue Ridge offer maximum groundwater potential in Rockingham County. This high-potential area stretches the length of the County and is capable of yielding many millions of gallons of water daily. It ranks as one of Virginia's better groundwater-producing areas west of the Coastal Plain province.

A number of factors combine to account for this remarkable high-potential area. The present-day flood plain and the older terrace deposits of the Shenandoah River are a mile wide in places and may exceed 100 feet in thickness. The terraces are step-like and are formed of alluvial material, mostly sand and gravel, deposited by the River as it flowed at higher elevations in the past. The extreme width can be attributed to extensive meandering as the River snaked its way along the western base of the Blue Ridge.

These unconsolidated sediments receive abundant recharge in the form of runoff, both surface and subsurface, from the west slope of the Blue Ridge. Groundwater is transmitted along bedding planes of the westward-dipping rocks and is channeled toward the South Fork via the alluvium. These conditions, plus the fact that the entire alluvial area is traversed by the River, account for the exceptionally high groundwater potential. In addition, the alluvium recharges the carbonate aquifers underlying the River, terraces and flood plain. In periods of high flow the stream acts as a source of recharge to the surrounding sediments. The area can be likened to a large sponge collecting runoff from the Blue Ridge and infiltration from the River.

The carbonate aquifers west of the South Fork of the Shenandoah River are far less productive than those overlain by the alluvial deposits, yet they offer a very good source of groundwater for both domestic and non-domestic supplies. It should be emphasized, however, that although these formations offer fairly good potential, their yield is highly variable and unpredictable due to their physical and chemical characteristics.

Some of the limestone in this region is susceptible to formation of extensive solution channels and cavities capable of producing large quantities of water. Other limestone units and some of the dolomite formations are less susceptible to solution action, yet they too are considered reasonably reliable water producers.

Structural conditions are a very important factor in determining the groundwater potential of the central valley since they create several distinct areas where the same water-bearing formation may be developed. The Massanutten Syncline has caused each of the Ordovician carbonate formations to surface twice between Keezletown and the South Fork of the Shenandoah River. Additional folding and faulting has caused most of these same units to appear at or very near the surface at several other places from Keezletown west to Little North Mountain. Faulting has fractured and sheared the rock to create numerous water collection areas in addition to determining the location of many of the units.

Pumpage from the carbonate formations, particularly those overlain by the alluvial and terrace deposits along the South Fork, can likely be doubled over present development. It is imperative, however, that responsible groundwater management practices are observed so that maximum potential may be realized.

The Martinsburg formation is principally a shale unit and does not have the potential for groundwater development common to the carbonate formations. A significant number of wells with marginal productivity have been drilled in the Martinsburg. It is more productive than the average shale unit, though, and is a fairly reliable domestic supplier. This is probably due to the possible existence of minor limestone beds and the calcareous nature of the shale; geologic structure may also be a contributing factor. The Martinsburg is one of the major folded units and serves as a large catchment for runoff from Massanutten Mountain. This folding combined with the probable fracturing along the axial portion of the Syncline enhances the groundwater capabilities of the formation.

Area West of Little North Mountain. Poor to fair groundwater potential is the rule in the western third of the County. All the Mississippian, Devonian and Silurian formations are principally shale, sandstone and quartzite units which are openly folded and have undergone relatively little deformation. The resultant lack of fractures leaves few places for groundwater to collect, store and move.

The only occurrence of these units east of Little North Mountain is in Massanutten Mountain. Though severely deformed, the rocks in this area offer extremely limited groundwater potential.

Groundwater Development

Groundwater is the principal source of water supply for the major portion of this County. Well over half the population is supplied by groundwater systems (excluding the independent city of Harrisonburg which is supplied by surface water). Five of the seven incorporated towns, Dayton, Elkton, Grottoes, Mt. Crawford and Timberville, use groundwater. Of these, all but Mt. Crawford has a public system. A large percentage of housing developments and industry tap groundwater resources, and virtually all domestic systems are supplied by wells or springs.

Daily groundwater withdrawal in Rockingham County is probably about 15 million gallons per day (mgd). Industry alone accounts for over 8 mgd; commercial systems utilizing groundwater account for less than 1 mgd. Public and domestic systems likely use close to 6 mgd. Virtually all industrial pumpage is derived from the terrace and flood plain deposits of the South Fork of the Shenandoah River, while most domestic, commercial and public supplies tap the central valley carbonate formations.

Groundwater development is confined mainly to the valley (including the South Fork alluvial deposits) between the Blue Ridge and Little North Mountain. Sparse domestic development has been accomplished in the higher elevations to the east and west, but very few data are available. The Kettle area of Massanutten Mountain has been developed commercially and is covered briefly in the following discussion.

The data presented below assumes no differentiation between domestic wells and those used for public, industrial or commercial supplies. In practical terms, developers of industrial and public systems will be able to spend a greater amount of money than the average homeowner interested in developing a domestic supply. Domestic wells, as a result, are generally shallower and equipped with smaller capacity pumps and consequently exhibit smaller yields than the larger wells necessary for industry and municipalities.

The Cambro-Ordovician carbonates and the Martinsburg formation have been developed to a far greater extent than the remaining formations. Table 3 shows the depth yield relationships for these two hydrogeologic units.

Carbonate Formations. Very few wells in carbonates in the County produce less than 10 gallons per minute (gpm). The average well yields 20-50 gpm, and many have production in the order of hundreds of gpm, though most of these tap formations overlain by alluvial deposits. Water zones may be encountered as deep as 500 feet, though seldom deeper, and it is common for a well to tap multiple water zones. Most wells in carbonates in the County are drilled approximately 300 feet, but

TABLE 3

AVERAGE YIELD (GPM) BY WELL DEPTH FOR THE CAMBRO-ORDOVICIAN CARBONATES AND THE MARTINSBURG FORMATION IN ROCKINGHAM COUNTY*

Depth (ft)	CAMBRO-ORDOVICIAN CARBONATES	MARTINSBURG FORMATION
0-99	410 (11)	No Data
100-199	24 (30)	11 (12)
200-299	118 (27)	111 (4)
300-399	192 (21)	68 (4)
400-499	39 (16)	6 (3)
Below 500	39 (22)	27 (7)

*Parentheses () indicate number of wells used in making yield calculation for a particulr depth. All yields rounded.

Source: Virginia State Water Control Board - VRO

wells in the 400-600 foot range are not uncommon.

The Beekmantown and the Edinburg formations are the two major water-bearing carbonate formations in Rockingham County with the exception of the Rome and Elbrook formations which are traversed by the South Fork of the Shenandoah River. According to available data, the average Edinburg well is around 250 feet deep and produces approximately 35 gpm. Depths range from 70-790 feet and yields range up to 250 gpm. Wells less than 200 feet deep have an average yield of around 15 gpm, and those deeper than 200 feet average from 20 to 50 gpm. Wells drilled from 400 to 500 feet deep have produced on the average around 25 gpm.

The Beekmantown seems to be the more productive of the two formations. From data collected thus far, it appears that better production is possible at shallower depths than is generally necessary in the Edinburg. Wells in the Beekmantown average around 350 feet in depth with an average production of about 45 gpm. Reported depths range from 90 to 800 feet, and yields range up to 313 gpm. Wells less than 200 feet have an average yield of nearly 30 gpm, and those greater than 200 feet average from 35 to 83 gpm. The greater average yield, 83 gpm, is for wells between 400 and 500 feet deep.

Two of the most notable Beekmantown wells are those supplying the town of Timberville (85 and 131). Both are drilled very close to the North Fork of the Shenandoah River and are likely recharged by the stream. Producing more than 250 gpm each, they bear out the fact that high yields are generally available in alluvial areas. A 309-foot well in Montezuma drilled in the alluvium bordering the Dry River yields 60 gpm, yet a well just across the river (230) yields only 15 gpm. The large difference is probably attributable to the latter well being drilled to a depth of only 105 feet.

Mud seams are commonly encountered in carbonate rocks, particularly in the Beekmantown and Edinburg formations. Mud seams are solution channels which have become filled with sediment by the continued process of water infiltration. The channel is generally able to transmit water, though it is extremely muddy, and must be pumped sometimes as long as a week before the water clears. Occasionally the water cannot be cleared, and the hole must be abandoned. Mud seams have been reported in every sector of the County underlain by carbonate rocks.

A very limited amount of data are available from the remaining carbonate formations. All of the units can likely be developed to yield small to moderate quantities of water with the highest potential available where alluvium-covered flood plains traverse the rocks. Table 4 lists depth-yield relationships for the major carbonate formations.

Martinsburg Formation. The Martinsburg formation is principally a calcareous shale unit with some possible limestone beds. Covering a large portion of the valley floor, the unit is one of the most important sources of domestic groundwater supplies but is less adequate and reliable for public and industrial systems.

The average domestic well in the Martinsburg unit is around 150 feet deep and produces little more than 10 gpm. Depths range from 120-220 feet, and the highest reported yield is 20 gpm. The average non-domestic well (commercial, public, industrial, institutional) is 470 feet deep and produces just under 60 gpm.

The highest yield reported from the Martinsburg formation is 325 gpm obtained from a 200-foot well (104) owned by the Massanutten Development Company on the eastern foot of Massanutten Mountain. Indeed, the only wells having a reported yield above 40 gpm are all owned by that Company. Three other wells (132, 133, 134) on the western slope of the Massanutten owned by them have all yielded over 100 gpm. All of these wells are situated favorably to receive recharge from the

TABLE 4

AVERAGE YIELD (GPM) BY WELL DEPTH FOR THE MAJOR CARBONATE FORMATIONS OF ROCKINGHAM COUNTY*

Formation / Depth (ft)	0-99	100-199	200-299	300-399	400-499	Below 500
Edinburg	4 (1)	14 (4)	50 (7)	21 (4)	24 (8)	55 (6)
Lincolnshire/ New Market		40 (1)	22 (5)			42 (2)
Beekmantown	28 (2)	29 (12)	55 (6)	63 (9)	83 (4)	34 (13)
Chepultepec	15 (1)	14 (2)		10 (1)		
Conococheague		39 (6)	18 (3)	130 (1)	14 (3)	
Elbrook	863 (5)	30 (1)		608 (2)		
Rome		40 (1)	757 (3)	508 (4)	60 (1)	

*Parentheses () indicate number of wells used in making yield calculation for a particular depth. All yields rounded to nearest gpm; blanks indicate no data available.

Source: Virginia State Water Control Board - VRO

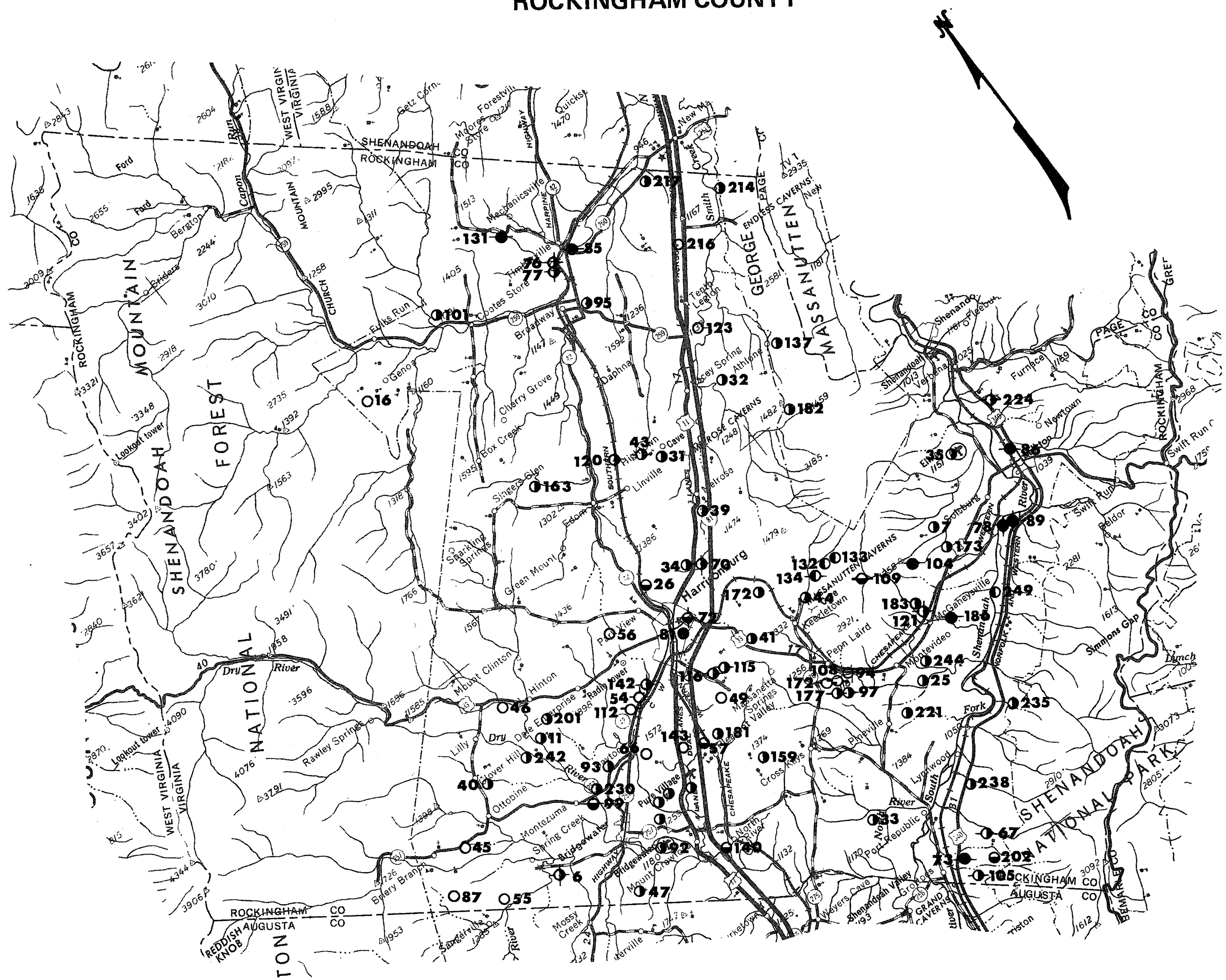
mountain slopes.

On the other hand, wells drilled in the Martinsburg where recharge conditions are less favorable usually produce meager amounts of water. A well (174) at Donnagail Subdivision was drilled to a depth of 910 feet and encountered only 8 gpm. Well (177) was drilled in the same area to a depth of 505 feet and yielded 25 gpm; two other wells taken to 608 feet each yielded only 6 gpm and 11 gpm, respectively. The wells at Donnagail also serve as a good illustration that drilling deeper will not always result in higher yields.

Water Well Development. The locations of approximately 100 wells are indicated on the accompanying map (Plate 8). They are representative of the County as a whole as far as density, total depth, static water level, yield and drawdown are concerned. In many cases several wells in the same area have been cited because quite often wells in similar geologic and topographic conditions will be totally different in many other characteristics. Often two wells less than 100 feet apart will vary significantly in yield, depth, and static water level as well as quality due to lithologic and structural differences. A complete listing of these and other wells, as well as definitions of some basic terms, is given in Appendix B.

Public Systems. Eighteen public systems are presently supplied by groundwater in Rockingham County. A public system

GROUNDWATER DEVELOPMENT
ROCKINGHAM COUNTY



LEGEND
WELL YIELDS

- ○ 10 GPM
- ◑ 10-49 GPM
- ◒ 50-99 GPM
- ◐ 100-199 GPM
- ● 200+ GPM

- ○ DOMESTIC WELL
- -○- PUBLIC WELL
- -○- INDUSTRIAL WELL
- 235 WELL NUMBER

SCALE 1:250,000

5 0 5 MILES

5 0 5 KILOMETERS

Source: Virginia State Water Control Board – VRO

PLATE NO. 8

is defined by the Virginia State Department of Health as one which serves more than 25 individuals or more than 15 residential connections.

The average depth of public supply wells in this County is between 425 and 475 feet. Yields range from 1 gpm to 1016 gpm. Aside from a few 10- and 12-inch wells, the great majority have 6-inch diameter casings.

Fourteen of the systems are drilled in carbonate rocks, nine of them tapping the Beekmantown formation. All appear to supply adequate volumes of water, and the Elkton well (86) which penetrates the carbonate rock underlying the South Fork alluvial deposits reportedly delivers better than 1000 gpm. A well (73) in this same geologic setting which supplies the town of Grottoes reportedly pumps 200 gpm with a drawdown of only five feet. The town of Dayton is supplied by Silver Lake (196), a spring-fed lake with a safe dry weather yield of about 5 mgd.

Construction and location of public water supply systems is regulated by the Virginia State Department of Health and must be in compliance with the requirements and standards described in Waterworks Regulations (Public Drinking Water Supply), published by that Department.

Industrial Systems. Few industries in this County utilize groundwater sources. The major user is the Merck and Company Chemical Division located on the east bank of the South Fork of the Shenandoah River just south of Elkton. Table 5 lists average daily pumpage figures for Merck for the years 1970-1975.

TABLE 5

AVERAGE DAILY GROUNDWATER WITHDRAWALS, 1970-1975
MERCK CHEMICAL DIVISION, ELKTON, VA.

YEAR	AVERAGE PUMPAGE (GPD)
1970	7,871,927
1971	9,019,155
1972	8,248,825
1973	7,863,024
1974	8,348,612
1975	7,231,851
6-year average	8,097,232

Source: Virginia State Water Control Board - VRO

The present flood plain and ancient terrace deposits are very thick here and are underlain by shale and limestone beds of the Rome and Elbrook formations. Five of the Merck wells bottom out in the Elbrook and four of them extend into the Rome; all are prolific producers. Reynolds Metals Co., located just across the Augusta County line in Grottoes, is currently pumping approximately 3 mgd from the same alluvial deposits.

The other industrial wells are, almost without exception, located in limestone units. Daily withdrawals range from less than 1000 gpd to nearly 80,000 gpd. Table 6 lists the major industrial users in Rockingham County and their average daily withdrawals.

Industrial well depths range from 68 to 615 feet and average around 235 feet. The deepest well (120), owned by Valley

TABLE 6

MAJOR INDUSTRIAL GROUNDWATER USERS IN ROCKINGHAM COUNTY

User	Average Pumpage (gpd)
Bond Lumber and Millwork	1,000
Jordan Bros. Hatchery	2,000
Merck Chemical Division	8,097,232**+
National Fruit Products	16,074**
Rockingham Sleepwear	1,297**
Sarco Corporation	12,000
Shen-Mar Food Products	14,225**
Superior Concrete	1,000
Valley Protein	19,000
Wampler Foods	77,760
TOTAL	8,241,588

+6-year average from Table 5
**Metered systems; all others estimated

Source: Virginia State Water Control Board - VRO

Protein at Linville, is the only industrial well known to be drilled in a shale formation. Well diameters are generally six inches or less with the exception of the Merck and Company wells. Several of these have diameters ranging from 14 to 20 inches.

Domestic Wells. Over two-thirds of the estimated 7000 domestic wells located in this County have been drilled in carbonate rocks, particularly the Beekmantown and Edinburg formations. The Beekmantown appears to be the most suitable domestic supplier and boasts half of the development. A large number have been drilled in the Edinburg formation, though it is typically a poor groundwater producer. The remaining carbonate formations are relatively well-suited to domestic water supply development.

Though shale is typically a very poor aquifer, the Martinsburg formation is an important domestic supplier in the study area. This is due to the existence of possible limestone beds and of many fractures, which is favorable to groundwater occurrence. The Devonian and Silurian shale and sandstone formations, however, are regarded as very poor groundwater units but may be developed for very small domestic supplies.

Domestic wells greater than 500 feet are uncommon. Only seven percent of those on file exceed that depth, and all are carbonate wells. There appears to be very little difference in drilling depth between the carbonate formations and the Martinsburg shale.

Diameters for all domestic wells on record, except dug wells, are between four and six inches. Dug wells usually range from 36 to 48 inches.

Production as a rule is under 20 gpm. Forty percent yield between 10 and 20 gpm; 30 percent yield less than 10 gpm. Of the remaining 30 percent, only three are reported to yield 50 gpm or greater. Beekmantown wells seem to be the most prolific as exemplified by two 40-gpm wells in the McGaheysville-Elkton area (35 and 244). Well (242) just north of Montezuma was tested at 30 gpm. Most Edinburg wells produce less than 10 gpm, and many are under 5 gpm. Martinsburg yields range between 10 and 20 gpm, while production greater than 3 or 4 gpm is rare in the Devonian and Silurian shale and sandstone units.

Springs. Springs are the result of a natural flow of groundwater to the surface and are important sources of water in the central valley portions of the County. At least four public water systems are supplied wholly or in part by springs, and smaller springs supply many domestic and farm operations. The most prolific and largest number of springs issue from the carbonate formations; smaller springs may be found in the shale and sandstone units. Hundreds of small springs and groundwater seeps are present in the Blue Ridge area, but very few have been developed as water supplies due to extreme seasonal fluctuations.

Some of the more notable springs include: Lacey Spring, nine miles northeast of Harrisonburg, reported to yield 4,000 gpm; Silver Spring which feeds Silver Lake at an approximate rate of 3,500 gpm and is the water supply for the town of Dayton; Bear Lithia Spring, a mile north of Elkton, yielding 1,000 gpm; the Massanetta Springs, four miles southeast of Harrisonburg, one of which flows at 400 gpm; the Town of Timberville Spring, which flows at a reported 275 gpm rate; the Town of Elkton Spring, with a reported yield of 175 gpm; Spring Creek, which feeds a large natural basin near Spring Creek Post Office reported to be greater than 90 feet deep; and Rawley Springs, the site of a late 1800's resort established around three small springs purported to have medicinal effects.

Tide Spring, four miles southwest of Broadway, is a very unusual spring in that it ebbs and flows periodically with no apparent regularity. According to Brent (1960), at times the flow exceeds 1,000 gpm; 15 minutes later the basin is often dry. Cady (1936) reported that only about 20 of these springs are known in the United States and a like number throughout the rest of the world.

CHAPTER V

GROUNDWATER QUALITY

Introduction

The quality of groundwater refers to its chemical, physical and biological characteristics. Groundwater contains dissolved mineral matter, has physical characteristics such as temperature, taste and odor, and may contain bacterial organisms. These factors are controlled in part by atmospheric gases, weathering and erosion of rock and soil, and the activities of man. Groundwater quality is highly influenced by the nature of the rock and soil with which it comes in contact since temperature, pressure and duration of contact determine the amount of dissolved minerals it contains.

Soil is nature's most efficient system of filtering water. Water infiltrating through thick soil cover stands an excellent chance of being purged of its harmful constituents or having them reduced to harmless concentrations. However, in areas where rock is exposed at the land surface, particularly in carbonate regions where the rock is prone to fracturing and solution activity, the water is introduced directly into the groundwater regime without the benefit of filtering. Lacking this cleansing action, it may carry chemical and biological pollutants which are capable of degrading the groundwater resources of an entire area.

More than 60 constituents and properties are frequently included in groundwater quality analyses. Many can be highly toxic and extreme health hazards, some are undesirable yet harmless unless in very unusual concentrations, and others are necessary for bodily functions and general good health. Parameters such as arsenic, cadmium, chromium, cyanide, mercury and lead are extremely toxic while others such as copper, iron, manganese and zinc are generally undesirable but may be hazardous in large concentrations. Any groundwater supply intended for drinking purposes should be analyzed by the Virginia Department of Health. Table 7 is a summary of common quality parameters, their recommended limits, and hazards and benefits associated with them.

Groundwater Quality By Hydrogeologic Area

Groundwater quality varies across Rockingham County by hydrogeologic area. Quality as a rule is good, but isolated problems do exist. Plates 9 and 10 depict hardness and total dissolved solids values, and Table 8 is a comparison of common quality indicators for the three hydrogeologic areas. A compilation of quality data appears in Appendix C.

Blue Ridge Area. Based on the limited quality information available for the Blue Ridge region, natural groundwater quality appears to be quite good. A limited amount of drilling has been done in Shenandoah National Park, and according to DeKay (1972),

TABLE 7

GROUND-WATER QUALITY PARAMETERS

Substance	Maximum Recommended Concentration (mg/l)*	Remarks
Bicarbonate	150	Seldom considered detrimental; lower amounts recommended for washing
Calcium	200	Seldom a health concern; may be a disadvantage in washing, laundry, bathing; encrustations on utensils
Chloride	**250 (Esthetics)	Taste is major criterion; generally not harmful unless in very high concentrations, but may be injurious to sufferers of heart and kidney diseases; sea water is 19,000 mg/l
Fluoride	**1.4 (Health)	Presence of about 1.0 mg/l may be more beneficial than detrimental; below 0.8 mg/l may cause mottling of teeth; extreme doses (4 grams) may cause death
Hardness	Range in mg/l of CaCo3 0-60 Soft 61-120 Moderately hard 121-180 Hard Above 180 very hard	Hard waters have had no demonstrable harmful effects upon the health of consumers; major detrimental effect is economic--values above 100 mg/l become increasingly inconvenient; wastes soap and causes utensil encrustation
Iron	**0.3 (Esthetics)	Essential to nutrition and not detrimental to health unless in concentrations of several milligrams; main problems are bad taste, staining and discoloration of laundry and porcelain fixtures
Magnesium	150	Not a health hazard because taste becomes extremely unpleasant before toxic concentrations reached; at first may have laxative effect on new users
Manganese	**0.05 (Esthetics)	Essential to nutrition but may be toxic in high concentrations; taste becomes problem before toxic concentrations reached; undesirable because it causes bad taste, deposits on cooked food, stains and discolors laundry and plumbing fixtures

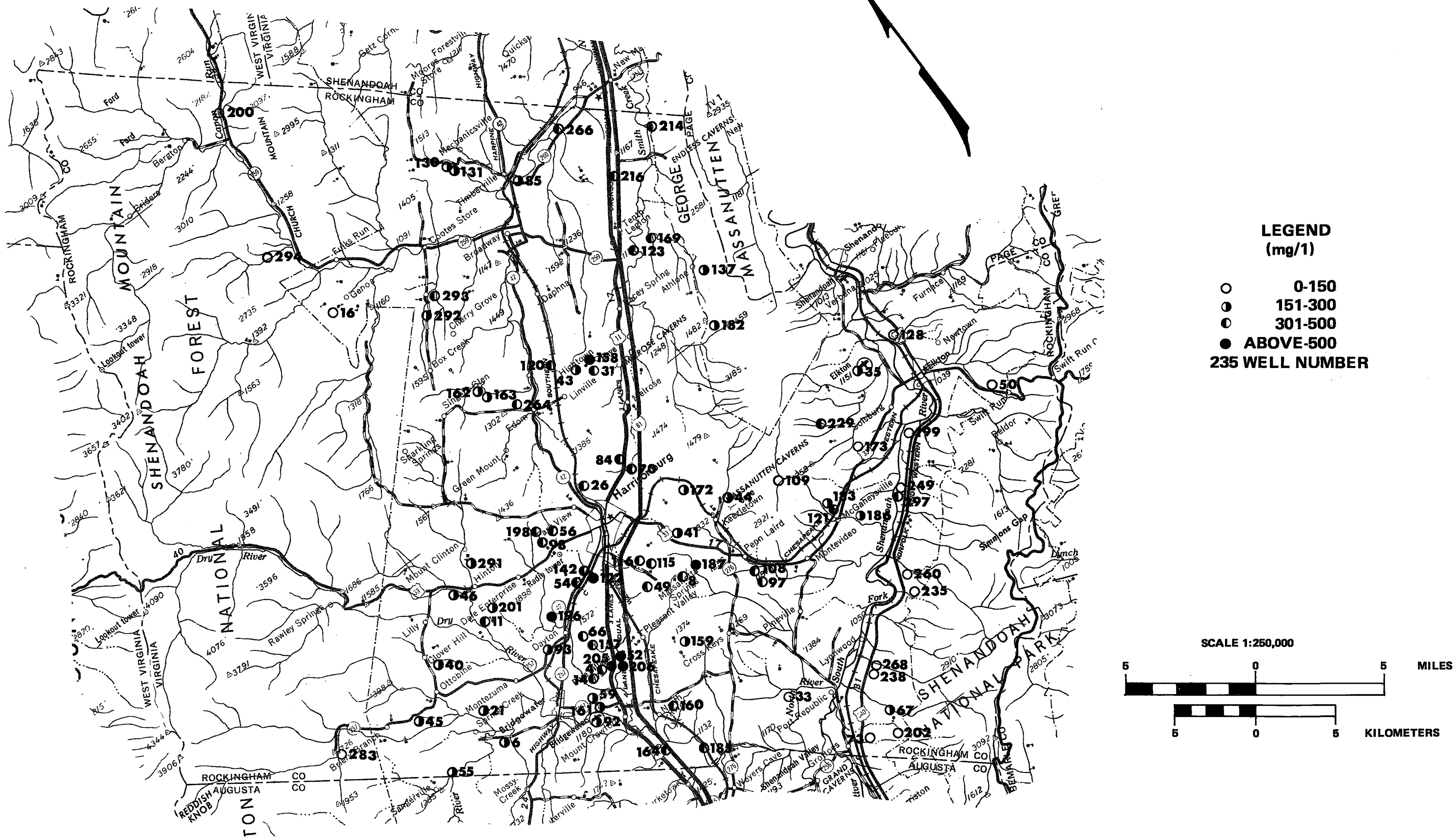
TABLE 7 CONTINUED

Nitrate	**10 as N, 45 as NO_3 (Appendix B listed as NO_3 , Health Department as N) (Health)	May be extremely poisonous in high concentrations; may cause disease in infants ("blue baby"); irritates bladder and gastro-intestinal tract, may cause diarrhea
pH	5.5-8	Indicates whether solution will act as an acid or base; water acquires "sour" taste below 4; high values favor corrusion control; efficiency of chlorination severely reduced when pH above 7
Potassium	1000-2000	May act as a laxative in excessive quantities
Sodium	100	May be harmful to sufferers of cardiac, circulatory, or kidney diseases; concentrations as low as 200 mg/l may be injurious
Solids (Total Dissolved	500	Not a health hazard above 500 mg/l, but may impart disagreeable taste, corrode pipes; general indicator of how highly water is mineralized
Specific Conductivity	1000	An indicator of the amount of dissolved solids in water; high concentrations can cause corrosion of iron and steel
Sulfate	**250 (Esthetics)	Above 250 mg/l may act as laxative on new users; may impart foul taste and odor

*Recommended concentrations based on current literature
**Actual limits established by the Virginia Department of Health; parentheses () indicate basis for limit

Source: Virginia State Water Control Board - VRO

DISSOLVED SOLIDS FROM SELECTED WELLS AND SPRINGS ROCKINGHAM COUNTY



Source: Virginia State Water Control Board – VRO

PLATE NO. 10

TABLE 8

GROUNDWATER QUALITY PARAMETERS:
AVERAGE VALUES (MG/L) BY HYDROGEOLOGIC AREA, ROCKINGHAM COUNTY

Parameter	Blue Ridge Area**	Central Valley Area		Area West of Little North Mtn. and Massanutten Mtn.
		Carbonate	Martinsburg	
Calcium	9.86+ (10)	82.47 (95)	76.91 (11)	24.25 (4)
Hardness (Ca-Mg)	24.60++ (10)	285.18 (95)	250.27 (11)	101.00 (4)
Iron	0.13 (16)	0.19 (55)	0.87 (6)	2.43 (4)
Magnesium	No Data	18.85 (95)	14.63 (11)	9.90 (4)
Manganese	0.10 (14)	0.037 (19)	0.01 (2)	0.25 (2)
Nitrate (as NO_3)	0.45 (15)	19.91 (69)	18.38 (6)	No Data
pH	7.46 (16)	7.67 (95)	7.72 (11)	7.03 (4)
Solids (Total Dissolved)	63.35 (8)	337.33 (82)	340.18 (11)	138.25 (4)
Sulfate	6.84 (16)	10.92 (29)	98.33 (3)	No Data

*Parentheses () indicate number of samples
** Values not in Rockingham County but taken from rock formations identical to those in Rockingham County, from DeKay (1972)
+Calculated from calcium hardness
++Calcium Hardness

Source: Virginia State Water Control Board - VRO

all wells sampled were very low in dissolved mineral matter. Values for both hardness and total dissolved solids consistently registered below 100 mg/l; a very few high iron values have been recorded.

Central Valley Area. The following discussion will delineate the two distinct quality trends characteristic of the carbonate formations and the Martinsburg formation. The Massanutten Mountain area, however, has not been included due to a total lack of quality information; the reader is referred to the section in this chapter entitled "Area West of Little North Mountain" since the two are hydrogeologically similar.

Total dissolved mineral matter in the carbonate rocks seldom exceeds recommended concentrations for potable water, but hardness commonly poses problems. Hardness in these formations averages approximately 285 mg/l. The corridor paralleling Route 11 between Mt. Crawford and Harrisonburg exhibits the three highest hardness readings in the County: 631 mg/l, 635 mg/l, and 997 mg/l at wells (52), (171) and (205), respectively. Values of 400 mg/l or higher are not uncommon in this corridor. McGaheysville and the area just east of Linville also show unusually high hardness readings.

Several of the individual carbonate formations produce water of varied hardness. The Concocheague limestone formation tends to be far below the County average, the mean being less than 150 mg/l. Well (45) near Ottobine has a hardness of

118 mg/l while Bear Lithia Spring (128) just north of Elkton has been measured at 78 mg/l. Water from both the Beekmantown and Edinburg formations averages above 300 mg/l in hardness, the latter being nearly 370 mg/l. The Route 11 corridor mentioned as having the highest hardness readings is underlain by the Edinburg.

Iron is fairly low in all the carbonates except for the Edinburg. As with hardness, several of the Mt. Crawford area wells are high in iron, and a few Edinburg wells elsewhere have produced water with iron concentrations as high as 1.0 mg/l. Average manganese values are well within the accepted limits for all carbonate units. Sulfate and chloride trends are well below average, but noticeably higher values for both parameters have been obtained in the corridor north of Mt. Crawford. However, none of these values exceed recommended limits. Sulfates of 25.4 mg/l and 16.4 mg/l for wells (209) and (210), respectively, are among the highest recorded in the County as compared with other carbonate wells exhibiting sulfates in the 5-to 6 mg/l range. The highest chloride reading, 83 mg/l, has been recorded in well (206), also located in this corridor.

Quality trends in the Martinsburg formation are distinctly different from the carbonate trends for most parameters. Owing to the fact that the unit is predominantly an extremely calcium-rich shale, hardness tends to be very high relative to other shale units but is still less than the carbonates with an approximate 250 mg/l average. Wells (4) and (14) two miles east of Bridgewater, however, are well in excess of 300 mg/l.

Iron and sulfur concentrations are decidedly higher than in the carbonates. The highest iron value recorded is 2.40 mg/l from the Bridgewater Air Park well (92). However, average iron content in the Martinsburg throughout the County is not above the Drinking Water Standards established by the Virginia Department of Health. Sulfate concentrations of 123.0 and 109.6 have been recorded from two wells (108 and 110, respectively) at Donnagail Subdivision.

Area West of Little North Mountain. Very few wells have been drilled in the Devonian, Silurian and Mississippian units of Rockingham County, and even fewer quality analyses are available. The only wells for which quality analyses are on file have been constructed in Devonian shale.

Quality trends in this area are typical of most shale regions. The pH is slightly lower than corresponding values for the carbonates and the Martinsburg, and total dissolved solids are significantly lower. The main benefit derived from wells in this area is the relatively low hardness. Although the water is classed as "moderately hard" since the average value is just above 100 mg/l, this is less than half the concentration found in other areas of the County. This is due mainly to the low concentrations of calcium and magnesium normally found in shale.

Extremely high iron concentrations offset the benefits of reduced hardness. In all cases on record, iron from the Devonian shale formations is in excess of State Drinking Water Standards; just east of Bergton values range from 0.7 mg/l to 3.70 mg/l in wells (200) and (199), respectively. Very high sulfate values are suspected, though no data are available for verification.

Suspected Groundwater Quality Problems

Isolated quality problems have been detected in a few places. Most of these problems are isolated cases of one or two parameters in excess of the Drinking Water Standards established by the Virginia Department of Health, though hardness presents problems in all areas except the Blue Ridge and the area west of Little North Mountain. One area, however, exhibits quality trends significantly different from those throughout the remainder of the County.

The area is a corridor approximately three miles long which roughly parallels U. S. Route 11 from Mt. Crawford to Valley Bowling Lanes, just south of Harrisonburg. The unusual samples appear to be confined to the Edinburg formation. Of 16 wells sampled along this stretch, eight have hardness values in excess of 350 mg/l; several exceed 400 mg/l, and well (205) has a calculated hardness of 997 mg/l. Iron values are high (0.4 mg/l) for two wells in the vicinity of the State Police Headquarters. Calcium values as high as 380 mg/l have been noted, chloride values are far higher than anywhere else in the

County, and nitrate values in excess of the Drinking Water Standards are not unusual. Possible petroleum contamination has been reported on several occasions.

Although most parameters do not exceed Drinking Water Standards, unusually high values may be either natural or man-induced phenomena and indicate potential quality problems.

Pollution

Groundwater pollution in carbonate areas can be prevented by careful management of all potential pollutants. Septic tanks have high potential for pollution in those areas where soil cover is thin. Barnyards and feedlots are also a potential problem because the County is highly developed agriculturally.

Pollutants may be introduced into solution channels via exposed bedrock and sinkholes and in areas lacking sufficient soil cover. Sinkholes are a major threat because people tend to use these depressions in the land surface for the disposal of trash, rubbish, dead animals, etc. The absence of an adequate soil cover at the bottom of the sinkhole means simply that water passing through the overlying rubble is not filtered of harmful constituents before it enters solution channels beneath the depression. These pollutants may spread to areas being tapped as groundwater sources by unsuspecting consumers.

Groundwater pollution is a more serious problem than stream pollution. There is no way to treat an aquifer system, so all purification must be done on an individual basis. Once pollutants enter the groundwater in carbonate regions, they may travel many miles in unpredictable patterns and persist for years.

Hydrocarbon contamination caused by leakage from fuel storage tanks, lines, or spillage from trucks is often a problem in carbonate areas. Two recent incidents have occurred at Lacey Springs and just south of Harrisonburg along U.S. Route 42. The source of the Lacey Springs incident is believed to have been an underground gasoline storage tank while the Harrisonburg problem was caused by an oil spill in a small stream which apparently entered groundwater and caused well pollution in the area.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Three major hydrogeologic areas have been identified in Rockingham County: the Blue Ridge; the central valley area; and the area west of Little North Mountain. In addition, the central valley contains three major units: carbonates overlain by the alluvial deposits of the South Fork of the Shenandoah River; the carbonate formations west of the River; and the Martinsburg shale.

The Blue Ridge area offers the lowest potential and is least developed. The rocks in this region are dense and afford very little chance for water to collect and move. Steep slopes reduce groundwater recharge. Ironically, water quality in this area is better than anywhere else in the County due to a very low content of dissolved mineral matter.

The area west of Little North Mountain, composed of Silurian, Devonian and Mississippian shale and sandstone formations, offers poor potential and is sparsely developed. Small domestic supplies can usually be developed in the area, but larger supplies cannot be realized. Hardness is relatively low; iron values tend to be in excess of Virginia Department of Health Drinking Water Standards. Associated high sulfate values are common.

The central valley offers the best groundwater potential. Maximum groundwater storage is possible in the alluvial and terrace deposits bordering the major streams, most notably the South Fork of the Shenandoah River. Limited industrial development has been accomplished in these units: Merck Chemical Division south of Elkton and Reynolds Metals, located just across the Augusta County line in Grottoes, presently withdraw a combined total of nearly 9 mgd.

Storage and movement in the central valley is highly variable and complex due to the erratic nature of solution channels in carbonate rocks. Industrial, commercial, public and domestic wells have been successfully developed in all the carbonate units, though mud seams are a recurring problem. Water quality is generally quite acceptable with the exception of very high hardness.

The Martinsburg shale formation offers fair potential and is a reliable source for domestic use. It should not be considered, however, for uses intended to be greater than domestic or small commercial uses. Water quality is nearly identical to that of the carbonate formations with the exception of iron and sulfate concentrations. These values tend to run far higher on the average and may exceed Drinking Water Standards imposed by the Virginia Department of Health.

Future development can likely double present development in all areas without adverse effects as long as responsible groundwater management practices are observed. Strict management is vital in the South Fork alluvial deposits to make optimal use of their groundwater potential.

Groundwater pollution, particularly in carbonate regions, can be prevented by careful management of all potential pollutants. Septic tanks, barnyards, feedlots and buried fuel storage tanks are potential sources of pollution in carbonate regions. Sinkholes are a serious threat to groundwater because they often are used as trash disposal areas and consequently introduce pollutants directly into the subsurface. In some cases, polluted groundwater may take generations to recover.

A corridor three miles in length between Mt. Crawford and Harrisonburg in the Edinburg formation has unusual quality relative to the rest of the County, though no major health problems have been noted.

Recommendations

(1) The alluvial and terrace deposits of the South Fork of the Shenandoah River and the underlying carbonate formations should be regarded as having the best groundwater potential in Rockingham County and could support large industrial demands.

(2) The central valley carbonate formations can usually be adequately developed for domestic, commercial, public and industrial supplies if well sites are selected to take maximum advantage of topography and geology.

(3) The Martinsburg formation can continue to provide adequate domestic supplies and limited supplies for small commercial and public uses.

(4) The Blue Ridge and the area west of Little North Mountain should be considered only for development of small domestic supplies.

(5) Quality should be the first consideration when considering groundwater as a supply in the U. S. Route 11 corridor between Mt. Crawford and Harrisonburg.

(6) Hardness should be a consideration when developing carbonate formations.

(7) When the need to develop groundwater arises:

(a) consulting hydrogeologists, well drillers and representatives of this Agency are available for information and advice;

(b) the State Department of Health must be contacted pursuant to developing a public supply well and should be contacted when developing a domestic drinking water supply;

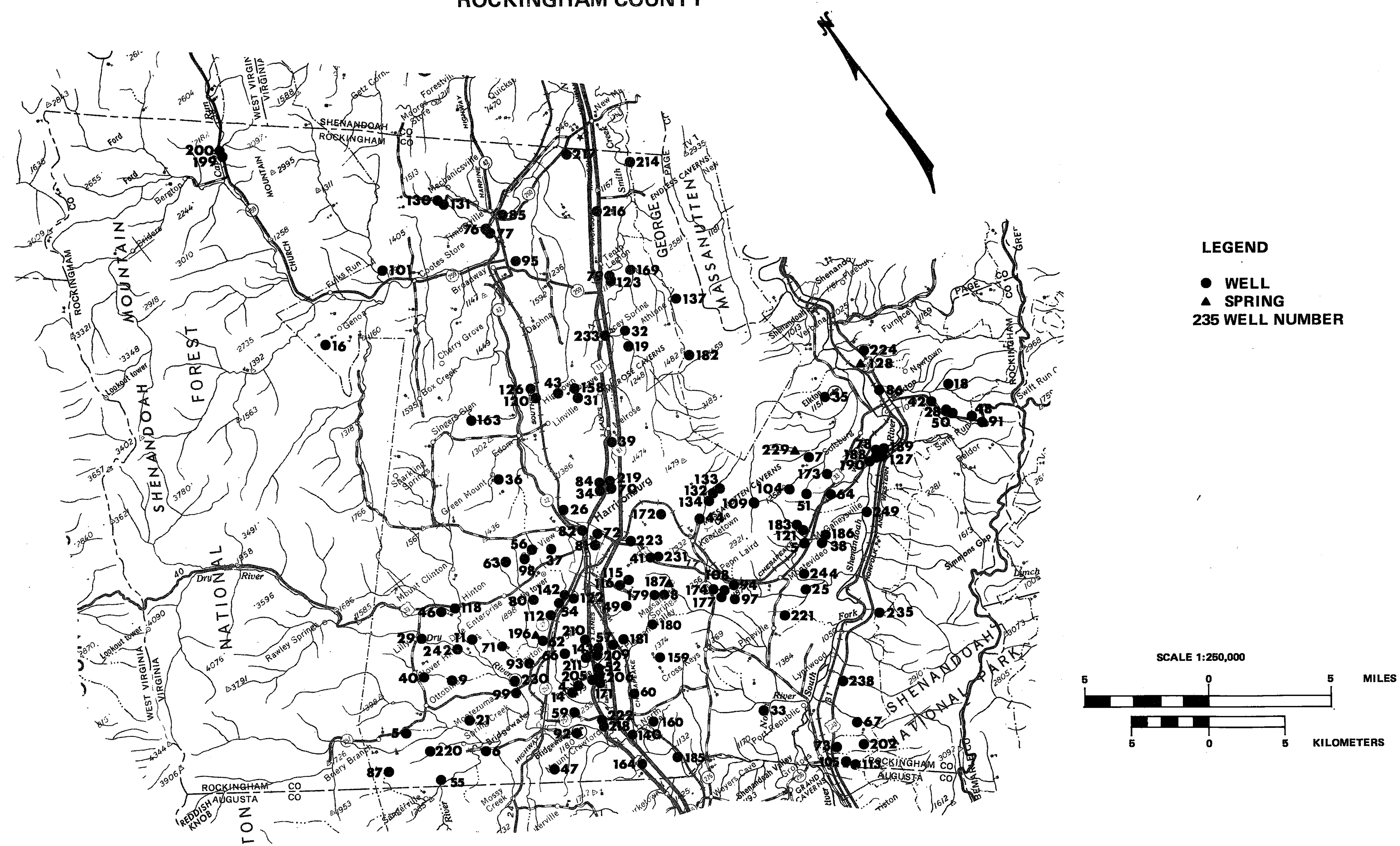
(c) reports and samples required by the Groundwater Act of 1973 are to be filed with the State Water Control Board.

APPENDIX A

MAP OF SELECTED WELLS AND SPRINGS IN ROCKINGHAM COUNTY

The accompanying Rockingham County map (Plate 11) shows locations for approximately 150 of the nearly 250 wells and springs indicated on the computer printout appearing in Appendix B. They are representative of the County as a whole as far as density is concerned. The numbers appearing next to each well/spring may be cross-referenced with the information contained in Appendices B and C.

SELECTED WELLS AND SPRINGS
ROCKINGHAM COUNTY



Source: Virginia State Water Control Board – VRO

PLATE NO. 11

APPENDIX B

SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY

The computer printout on the following pages lists basic well data for wells in Rockingham County. This printout is updated frequently to include information from new Water Well Completion Reports which are constantly being submitted by water well drillers. The information under the heading "Aquifer" may be cross-referenced with Table 2, Chapter III.

V I R G I N I A S T A T E W A T E R C O N T R O L B O A R D

B U R E A U O F W A T E R C O N T R O L M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY

****

THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH "GEOLOGIC MAP OF VIRGINIA" (DIVISION OF MINERAL RESOURCES - 1963)

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
1	W C WHISSEN	64	D	1265	161	3					OMB	7	3				DOM
2	LEE ROY PRICE	64	D	1278	191	10	5		104	106	OMB		2				DOM
3	JOHN O GARDNER #4	64	D	1262	161	12	5				OMB		4				DOM
4	BRYAN A BLAND	64	D	1270	220	7	5				OMB		4				DOM
5	MILDRED FAHRNEY	66	D	1268	131	23	5				OMB						DOM
6	JORDAN HATCHERY #2	62	D	1280	498	36	5		158	183	CCO	44	38				IND
7	GEORGE K HARDING #1	66	D	1160	120	37	5		69	70	OMB		12				DOM
8	ELSIE HARLEY #1	63	D	1450	283	10	5				OB	80	10				DOM
9	GLEN A HEATWOLE		D	1480	258	47	5				CCO	48	3			3	DOM
11	DAVID E HEATWOLE #2	63	D	1320	208	21	5		76	77	OB	44	12	56	.21	4	DOM
12	HERBERT HOLLEN #1	59	D	1260	125	40	5				OMB						DOM
13	WELDON GRIMSLEY	60	D	1060	90	46	5		69	90	OCH	60	15			10	DST
14	IRVAN D HUMMEL #1	63	D	1255	123	17	5				OMB	15	19	105	.18	1	DOM
15	CHARLES J KEENAN #1	66	D	1180	350	21	5				OB						DOM
16	ORIE MUMBERT	61	D	1280	236		5				DMO	35	2			2	DOM
18	JERRY MONGER	75	D	1200	145	120	6				CERU		25			2	DOM
19	LACEY SPRINGS SUBDIV	74	D	1160	437	48	6		210	218	OE	95	30	210	.14	72	PUB
21	JAMES D ECKARDT #1	63	D	1325	163	33	5				CCO	75	20				DOM
23	ROBERT Y FRAZIER #1	63	D	1745	650	6	5				OB	228	3			3	DOM
25	AVIS R BURKE #1	67	D	1122	300	47	5		185	186	OCH		10				DOM
26	JAMISON BLACK MARBLE	64	D	1375	415	14	7				OE	32	75				IND
28	DEAN LUMBER CO #1	65	D	1360	278	15	5		98	143	CWU		10				ABD
29	LILY GARDENS #2	64		1426	151		10		87	88	CCO	22	102			744	PUB
30	W W AREY & SON	65			181	106	5					85	20				COM
31	O W ADAMS & SONS #1	66	D	1266	410	18	5		153	154	OB	116	48				COM
32	MIKE A ARBAGAST	61	D	1235	213	20	5				OE	42	15			7	DOM
33	CALVIN BAKER #1	61	D	1180	169	8	5		58	59	OMB	48	20			2	DOM
34	BAR-B-CUE RANCH #1	61	D	1320	281	12	5				OLN/OE	69	20				COM
35	MRS J R BLOXOM	63	D	1100	198	57	5				OB	62	40				DOM
36	CARLTON BAILEY	59	D	1282	502	7	5				OMB						ABD
37	THERON CAMPBELL #1	63	D	1400	87	5	5				OE	22	4	58	.06	3	DOM
38	JOHN H BURNER #1	63	D	1085	238	27	5				CCO		38			5	DOM
39	THOMAS SALYER	60	D	1240	411		5				OE	85	12			2	COM
40	LAWRENCE E CLINE #1	65	D	1445	226	103	5				CCO		15				DOM
41	RICHARD D AREHART	65	D	1565	511	103	5				OB	100	10			6	DOM
42	RANCH HOUSE RESTAURNT	59	D	1160	104	3	6				CERU	15	20			3	DST
43	FIELD UNIT #8 (#1)	64	D	1316	390	62	7				OB	148	20	57	.35	24	PUB
44	C J CRIDER #1	59	D	1340	170	16	6				OB	16	15			2	DOM
45	DAVID R CUPP #1	65	D	1390	489	41	5				CCO		3				DOM
46	H L CUSTER #1	67	D	1340	175	28	5		106	175	CCO		5				DOM
47	MRS HENRY M DAVIS #1	66	D	1325	175	19	6	5	65	70	OMB	50	15				DOM
48	ELMER L SHIFFLETT JR	59	D	1280	126	14	6		126		CWU	20	12	106	.11	2	DOM
49	MRS M J DEAN #1	61	D	1412	102	41	5				OB	38	3			5	IND
50	J A DEAN	59	D	1320	216	30	6		216		CWU	59	18	157	.11	2	DOM

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SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY   PAGE 3

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
51	J HARMAN	64	D	1350	128	80	5				OMB	30	15				DOM
52	VALLFY LEE MOTEL	68		1195	200		6		95	100	OE	40	25				COM
54	DAYTON TRANSPORT	61	D	1270	439	2	5				OE	40	6	299	.02	3	IND
55	JAMES D SHULL #1	66	D	1318	173	22	5				CCO	46	6				DOM
56	A RAY BENTCH #1	62	D	1445	573	73	5				OLN	70	3			6	DOM
57	CONTINENTAL PHONE #1	61	D	1220	147	10	5		77	81	OB	48	75			21	ABD
58	CONTINENTAL PHONE #2	62	D	1220	198	25	5		152	156	OB	38	20	82	.24	9	ABD
59	CHARLES G KOOGLER #2	63	D	1320	163	25	5		115	118	OMB	60	11	80	.13	2	DOM
60	O W JORDAN #1	65	D	1200	475	12	5		102		OB		1				DOM
61	CHARLES G KOOGLER #1	63	D	1316	223	49					OMB	50					DST
62	SHEN VALLEY MEAT PROC	67		1222	200		6		185	200	OB/OLN	80	6			6	IND
63	HOWARD KNICELY	69		1415	182				148	150	OB	73					DOM
64	LEISURE LIVING TR PK	69	D	1140	316	68	7		196	204	OB	72	104	63	1.65	10	DOM
65	J H WENGER #2	69	D	1266	295	18	6				OLN/OE	20	2				COM
66	J H WENGER #1	69	D	1266	295	20	6				OLN/OE	23	5				COM
67	MADISON RUN TERRACE	69	D	1175	215	190	6		212	215	CR	135	20	15	1.33	48	PUB
68	BANK MENNONITE CHURCH	49		1340	103	33	6				OB	50	15	50	.30	2	INS
69	VILLAGE INN #1	68		1200	305		6		100	105	OE	35	25				ABD
70	DOUGLAS PEARCE INC #3	68		1290	451		6		449	451	OE	80	40				IND
71	MARTIN HARNESS SHOP	69	D	1355	218	18	6		170	180	OB		12			36	COM
72	METRO PANTS CO #1	51		1343	600	14	8		170	200	OE	18	75	200	.37	15	IND
73	TOWN OF GROTTOES	49	D	1185	303	150	12	8	265	303	CE	152	200	5	40.00	24	PUB
74	PLEASANT VAL S-DST #1	69	D	1425	600	35	6		510	511	OB	95	5			12	PUB
75	PLEASANT VAL S-DST #2	70	D	1390	645	80	6		562	565	OB		138	143	.96	72	PUB
76	ROCKINGHAM POULTRY #4	60	D	1020	424	17	7		74	75	OE	39	15	400	.03	2	ABD
77	ROCKINGHAM POULTRY #3	60	D	1030	622	23	7		75	78	OE	42	30	300	.10	2	ABD
78	MERCK & CO #8	49	D	975	70	19	18	14	50	70	CE	20	1175	5	235.00	24	IND
79	W VICTOR PRINGLE	61	D	1100	418	7	5		287	288	OMB	50	1	400		2	ABD
80	BERNARD MARTIN	49		1310	307	1	6				OB		2				COM
81	JOSEPH NEY'S	50	D	1340	227	6	8		62	63	OF	14	250	26	9.61	12	ABD
82	VALLEY OF VA MILK #3	49	D	1370	497	20	10		14	2015	OE	6	15	197	.07	24	ABD
83	VALLEY OF VA MILK #4	49	D	1355	302	76	8	6	116	117	OE	31	24	209	.11	28	ABD
84	COACHMAN INN	69		1280	351		6				OE						COM
85	TOWN TIMBERVILLE #1	61	D	1015	270	20	6		264	268	OB	32	270	260	1.03	50	PUB
86	TOWN OF ELKTON	65	D	960	352	71	12				CE	22	1016	84	12.09	46	PUB
87	HUMMEL ESTATE	61	G	1465	485	120	5		142	143	CCO	58	2	480		2	DOM
88	SHENGAS CORP	61	G		192	12	5		130	131	OB	30	70	190	.36	26	IND
89	POTOMAC RIVER PROJECT		E	1340	392		6				OMB	70					GOV
90	RICHARD WARMBIER #1	70		1185	352				20	50	OMB	20	4			1	COM
91	PENNY'S MOTEL	70	D		120	46	6		111	114	CW	28	40			2	COM
92	BRIDGEWATER AIR PARK	72	D	1175	290	50	6		117	120	OMH	5	40			2	COM
93	D R SHOWALTER	70	D	1268	172	36	6				OH	18	18			1	DOM
94	RICHARD WARMBIER #2	70		1175	301		6				OMB		1			1	COM
95	BROADWAY MOTEL	70		1220	800		6		799	800	OB	110	30			3	COM

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
96	U S GOVERNMENT	70	D	1100	310	30	6		126	132	CCO	71	130			27	GOV
97	DONNAGAIL #1- WELL #2	73	D	1260	815						OMB	80	18			3	PUB
98	GAILCRIST SUB	65		1380	300		6				OB		18	6	3.00	2	PUB
99	COUNTRYSIDE ESTATES	70	D	1220	309	12	6		124	125	OB	15	60			3	PUB
100	JACKSON CREEK FARMS	70	D	1335	675	23	6		280	283	OE		4			3	COM
101	VDH - COOTES STORE	72	D	1150	110	15	6		61	62	DMO/DB	35	38	108	.35	2	GOV
102	MASSANUTTEN DEV CO #1	71	D	1260	400	15	6		40	41	OMB	35	1	395		1	ABD
104	MASSANUTTEN DEV CO #3	71	D	1240	200	9	6		125	126	OMB		325	60	5.41	72	PUB
105	D VIA, JR	71	D	1200	300	100	6		240	245	CR	175	30				PUB
106	MASSANUTTEN DEV CO #2	71	D	1250	202	32	6		32	33	OMB	2	75			72	PUB
									141	143							
108	DONNAGAIL SUB #2	72	D	1240	357	17	6		190	191	OMB	20	7			2	PUB
109	MASSANUTTEN DEV CO #4	72	D	1760	397	42	6				DMO	25	51			1	COM
110	DONNAGAIL #1- WELL #1	72	D	1260	412	4	6		201	202	OMB	16	15			1	PUB
112	DAPIKE SUB	72	D	1270	790	14	6		425		OE	30	7			2	PUB
113	DMR OBS WELL #65	66	D	1225	350	57	5				CR	150	3				GOV
114	ASHBY HEIGHTS #1	60		1415	480		6				OB	87		253		73	PUB
115	ASHBY HEIGHTS #2	61		1505	615	15	6				OB	286	13			72	PUB
116	ASHBY HEIGHTS #4	64		1370	621	10	6				OB	10	26				PUB
117	ASHBY HEIGHTS #5	68		1355	405	7	6				OB	200	26			72	PUB
118	WAMPLER FOODS INC	55		1360	268	5	6				OB	150					IND
119	LILLY GARDENS #1	64		1430		151					CCO		86				ABD
120	VALLEY PROTEIN INC #1	63		1215	615	1	6				OMB	150	24	55	.43	24	IND
121	BOND LUMBER CO	29		1210	215						OLN/OE	48	30				IND
122	SARCO CORPORATION	50		1360	200						OMB						IND
123	VA DEPT OF HIGHWAYS		D	1100	500	2	6		111	112	OMB/OE	50	2			8	GOV
124	WAMPLER FOODS INC	72	D	1340	515	5	6		130	131	OB	25	15			2	IND
125	HITE SPRING (ELKTON)			1025							CR		200				PUB
126	VALLEY PROTEIN (SPRG)			1210							OMB		20				IND
127	MERCK & CO #2	41									CR						IND
128	BEAR LITHIA SPRING			930							CE/CCO						DOM
129	MCGAHEYSVILLE SCHOOL	50		1160							OB						ABD
130	TIMBERVILLE SPRING			1260							OB						PUB
131	TOWN TIMBERVILLE #2	66		1010	418		16	10	232	241	OB	57	257	58	4.43		PUB
132	MASSANUTTEN DEV CO #6	73	D	1520	392	27	10	6	290	300	OMB	31	122	214	.57	131	COM
133	MASSANUTTEN DEV CO #9	73	D	1525	393	51	10	6	130	131	OMB	43	144	281	.51	72	COM
134	MASSANUTTEN DEV CO #5	73	D		500	50	6		160	170	OMB	15	100			2	PUB
135	MASSANUTTEN DEV CO #8	73	D	1480	525	22	6		119	120	OMB	10	10			1	COM
136	MASSANUTTEN DEV CO #7	73	D		500	16	6		300	400	OE	26	2	499		1	COM
137	KAMPGROUND OF AMERICA	73	D	1205	319	17	6		65	66	OB	25	30	127	.23	24	COM
138	COMSONICS INC	73		1420	245		6				OB	30					IND
139	THE VILLAGE INN #2	73		1200	105		6		70	75	OE	30	30				DST
140	NORTH RIVER STP	71	D	1165	227	27	16	6	153	169	OLN	41	52	110	.47	48	DOM
141	USGS OBSERVATION WELL				310		6										GOV
142	DAIRYMEN SPECIALTY CO	67		1270	250				230	231	OE		10				IND

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SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
143	STATE POLICE DEPT	63		1230	201		6				OE	60	5	1	5.00	24	GOV
144	ROBERT POWERS	75			125		6					20	10	120	.08	20	DOM
145	LOUGH BROTHERS	75	D	1255	170	5	6				OE	10	20	170	.11	4	DOM
146	DONALD R WITTERS	74		1285	168		6		150	155	OMB		10				DOM
147	DON CROYER #2	75		1420	160		6				CE		1				DOM
148	WAMPLER HATCHERY #1	75		1290	200						OE		20				IND
149	WAMPLER HATCHERY #3	75		1290	505		20				OE		1				IND
150	MASSANUTTEN CAVERNS	71		1390	125		6		75	77	OB	15					ABD
151	MRS FLORENCE SPITZER			1145							OE						DOM
152	BUSHONG	46			50												DOM
153	KENNETH R HINKLE	75	D	1300	160		6		125	135	OB	93	8				DOM
154	OLIN W VAN PELT	65			120												DOM
157	J H WENGER (SPRING)			1260							OB						DOM
158	O W ADAMS			1230							OB						DOM
159	H PAUL MARTIN	73		1422	212		6				OB	10	20				DOM
160	DAVID E FRYE			1370	710		6				OB						DOM
161	W WILL (SPRING)			1200							OMB						DOM
162	TIM TAYLOR (SPRING)			1280							OB						DOM
163	RAYMOND PRINCE	74		1320	158		6				OB		15				DOM
164	W E NEFF	74		1130	177		6				OB	10					DOM
169	C W FLEMING			1080	70						OF						DOM
171	THE VILLAGE INN #3	73	D	1215	305	40	6		98	99	OE		30			4	COM
172	LTJ CONSTRUCTION CO	74	D	1510	365	80	7		350	351	OB	135	10			2	DOM
173	JULIAN THOMPSON	72		1170	190		6				OB	100	15				DOM
174	DONNAGAIL #2-WELL #3	74	D	1250	910	9	6				OMB		8				PUB
175	DONNAGAIL #2-WELL #4	74	D	1220	608	20	6		228	231	OMB	2	6			1	PUB
176	DONNAGAIL #2-WELL #5	74	D	1220	608	6	6		74	78	OMB	1	11			1	PUB
177	DONNAGAIL #2-WELL #6	74	D	1280	505	12	6		85	86	OMB	75	25			1	PUB
178	BOARD SUPERVISORS #1	74	D	1270	500	35	6				OB		25			40	ABD
179	BOARD SUPERVISORS #2	74	D	1400	500	26	6		123	147	OB	29	138			72	ABD
180	BOARD SUPERVISORS #4	74	D	1330	502	17	6		55	56	OB		20			12	ABD
181	C THOMAS CALLENDER	74		1270	503		6				OB		12			1	DOM
182	CHARLES MONGOLD	74	D	1530	135		6		125		OLN/OE	85	40			1	DOM
183	JACK HENSLEY	75	D	1205	110	6	6				OE	8	10	110	.09	1	DOM
184	ROCKINGHAM POULTRY #1	60			504	10	10	6			OE	22					ABD
185	JOHN HORST	74	D	1120	300		6				CCO	30					DOM
186	MCGAHEYSVILLE WATER	64		1125	390	38	6		370	375	OB	87	313	96	3.26	48	PUB
187	MASSANETTA SPRINGS			1380							OB						PUB
188	MERCK & CO #1	41		996	213		6		200	213	CR	37	350	50	7.00		IND
189	MERCK & CO #3	42		995	307		14		80	85	CR	45	1000				IND
190	MERCK & CO #4	42		1000	390		14		381	385	CR	75	1000				IND
191	MERCK & CO #5	43		975	68		20		45	52	CE	2	1200				IND
192	MERCK & CO #6	46		975	68		8				CE	20	1000				IND

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193	MERCK & CO #7	47		975	68						CE	22	900				IND
194	MERCK & CO #9			975	68						CE						IND
195	MERCK & CO #12	71	D		260	44	30	20			CR	69	1900				IND
196	DAYTON (TOWN-SPRING)										OB						PUB
197	ROCKINGHAM POULTRY #2	60			273		10				OE	36					ABD
198	ROBERT J GORDON	75	D	1450	90	7	6		73	75	OB		25				DOM
199	GREEN VAL MED CLIN #1	49		1460	80						DCH						COM
200	GREEN VAL MED CLIN #2	59		1460	100		6				DCH						COM
201	FLOYD KNICELY	75	D	1375	380	68	6				OB	60	12			1	DOM
202	CLEADUS MEADOWS JR	75	D	1255	400	370	6				CR		60			2	DOM
203	SALEM CARPETS			1245							OE						COM
204	DENNIS EARLY			1225	200						OE						DOM
205	KERMIT EARLY	64		1245	250		5		217	218	OE	79	8	100	.08	2	DOM
206	J W HONEYCUTT			1190	175						OE						DOM
207	MRS T J JENNINGS			1225	154						OE	22					DOM
208	DAVID H LISKEY			1210							OE						DOM
209	DR WILLIAM E REISH			1215	90						OE						DOM
210	REBEL'S ROOST MOTEL			1255	550						OE						COM
211	ROCKINGHAM MOTEL			1235	300						OE						COM
212	TUMBLEWEED MOTEL	64		1215	230		6				OE	35	10				COM
213	VALLEY LANES INC			1275							OE						COM
214	ROGER BARLOW #1	63	D	1030	138	13	5				OMB	45	13				DOM
215	FLEMING POULTRY #1	62	D	1140	153	1	5				OB	10	6			2	DOM
216	CHARLES M GERRY #1	62	D	1125	303	5	5				OE	51	3				DOM
217	R L COMPTON	65	D	1085	121	19	5		105	106	OCH	40	12				DOM
218	BURGESS SERVICE STA	61		1195	192		6		100	170	OE	30	12	70	.17	5	COM
219	BURNER WELL DRILLING	75	D	1290	775	7	8		440	478	OE	55	212	319	.66	101	PUB
220	CLYDE LAMBERT	74		1335	140		6				CCO		16				DOM
221	C L MORGAN	74		1135	155		6				OCH		16				DOM
222	MT CRAWFORD RURITAN			1205							OE						DOM
223	NEFF TRAILER SALES	60	D	1445	412	95	6				OE	69	1	380		2	PUB
224	ROCKINGHAM SLEEPWEAR	58		1035	160						CE		30				PUB
225	SPRING CREEK			1290							CCO						DOM
226	TRINITY CHURCH	61		1200	260		5		180	190	OE		50	258	.19	2	INS
227	VALLEY TRAILER PARK	74	D	1345	540	55	6		379	380	OLN		80	540	.14	6	DOM
228	EMMERT F RITTINGER	60		1275	125		5				OMB	40	6				DOM
229	BLOOMER SPRING			1125							OMB						DOM
230	DANIEL BRUBAKER	75	D	1235	105	4	6		95	105	OB	30	15	105	.14	3	DOM
231	CARPER				505		6				OH		12			2	DOM
232	CLAYTON		D		65						CR	20	24			1	DOM
233	SUE & LARRY CRAUN	71		1115													DOM
234	CAPLINGERS CHURCH	75			94		6					12	20	30	.66	1	DOM
235	SHEN CRAZYHORSE CAMP	73		1245	252	202	6				CS		15				COM
236	RONALD DAVIS	41		1120													DOM

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SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
237	DEAN		D		145							40			2	DOM
238	HOWARD DEAN JR	75		1080	118	300	6			CR	118	40				DOM
239	ROBERT DEAN	74		983	75		52			CE		40				DOM
240	DOUGLAS PEARCE #2			1295	110					OE		5				IND
242	HARRY ESTEP	74	D		90		6			OB	30	30	62	.48	4	DOM
243	DUANE FAIRWEATHER			1120						OE						DOM
244	FARAWAY FARMS	75	D		140		6			OB	65	40	140	.28	2	DOM
245	KNIGHT #1				65		6				20				1	DOM
246	KNIGHT #2		D		250						90	12			2	DOM
247	BOB FRAZIER			1405						OE						DOM
248	I J GARBER	74			185		6				40	6			3	DOM
249	MRS HUNTER GIBBONS #1	74		981	73		6			CE		100				DOM
250	GODFREY	75	D		95		6				20	10				DOM
251	GLEN HEATWOLE	74			105		6				3				3	DOM
252	M W HEATWOLE	75			205		6				35	6			3	DOM
253	PAUL&IMOGENE HENSLEY			1140	158		6				137	15				DOM
254	ROBERT HINKLE	74			110		6				35	30			3	DOM
255	DON KLINE			1260	220		6					20				DOM
256	E C HOSLEY	74			245		6				48	6			3	DOM
257	CONTRACTOR D LAMBERT	74			135		6				90	4			3	DOM
258	LEO L LISKEY	74			605		6				35	1			3	DOM
259	CHARLES MATTHEWS	75			100		6				40	5	100	.05		DOM
260	JIM MICHAEL (H J JR)	73		1140	160		6					15				DOM
261	VALLEY OF VA COOP #1	30		1355	251		10					55				DOM
262	VALLEY OF VA COOP #2	45		1360	1365		10					60				DOM
263	A J MILLER	75			65		6				21	15			3	DOM
264	DON MILLER	75		1250	141		6				15	300				DOM
265	FERN MITCHELL			1095												COM
266	R R RENALDS	60		960	80		5					50	80	.62	2	IND
267	RODERICK (MILLER FARM	75	D		270		6				6	5			1	IND
268	PAUL SAYRE	72		1080	160		6				20	10				DOM
269	JOHN SHOWALTER	75			285		6				42	10			3	DOM
270	VEYNOR SIMMONS JR	75	D		100		6				20	15	70	.21	4	DOM
271	FRED EVERETT SMITH			1045	388		18					8				DOM
272	SOUTHERN STATES COOP			1330												PUB
273	SUPERIOR CONCRETE			1375												PUB
274	THREE S BUILDERS	75			185		10				38	10			3	DOM
275	THREE S BUILDERS	75			125		6				40	6			3	DOM
276	CONTRACTOR TROYER	74			605		6				35	1			3	DOM
277	W M TURNER	75			125		5				20	20	10	2.00	1	DOM
278	W M TURNER	75			125		6					10	70	.14	1	DOM
279	RAY WENGER	75	D	1370	312		6				45		140		8	DOM
280	WILLIAM E WHITE			1130												DOM
281	MRS BERRY	75		1300	67		6					30				DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR ROCKINGHAM COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
282	HAROLD HALTERMAN	74		1450	175		6					3				DOM
283	CARR COFFMAN			1725	56		6									PUB
284	ALLAN MORRIS			1375	100		6					15				PUB
285	EARL HARTMAN	73		1325	410		6					5				PUB
286	LESTER REVERCOMB			1540	30		6									PUB
287	W NEIL TURNER	75			125		5				20	20	10	2.00	1	DOM
288	W NEIL TURNER	75			125		6					10	70	.14	1	DOM
289	CHARLES MATHIAS	75			100		6				40	5	100	.05		DOM
290	CAPLINGERS CHURCH	75			94		6				12	20	30	.66	1	DOM
291	ROY FRANK	71		1355	80		6					40				DOM
292	C S MUNDY QUARRY			1380												DOM
293	NEFF LUMBER MILL			1255												DOM
294	J & J CUNNINGHAM			1365	36		6				12					DOM
295	JORDAN BROS HATCHERSI	58		1280												INS
296	RANDOLPH F CARICOFE	71		1295	279		6					30				DOM
297	MRS HUNTER GIBBONS	49		985	70											DOM
298	SHEN-MAR FOOD PRODUCT			1190	175											DOM
299	ROBERT STERRETT	65		1260	128		6					16				DOM
300	MR DAVID HIVELY	75	D		100						50	15				DOM
301	CLAUDE E RAYNES	75	D		175		6				129	13			2	DOM
302	RIGGLEMAN	75			300		6					15			1	DOM
303	RITCHIE				500		6				10	1	460		1	DOM
304	COOPER FARM BUREAU															DOM
305	ALLEN N ZIMMERMAN				60											DOM
306	BROADWAY METAL WORKS			1065	80											DOM
307	HARRY HAMILTON		D		315							100				DOM
310	NIELSEN CONST CO INC											5				DOM
311	EVELYN RICHARDSON	76	D		205		6				52	20			3	DOM
312	TOWN OF ELKTON															DOM

APPENDIX C

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

The computer printout on the following pages lists basic groundwater quality data available for many of the wells listed in the water well data summary (Appendix B). There are some quality analyses listed for wells not included in Appendix B; however, well data is available for these wells and may be obtained by contacting the State Water Control Board's Valley Regional Office in Bridgewater or the Headquarters Office in Richmond.

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

DATE 08/10/76

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

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THE FOLLOWING LIST OF GROUNDWATER QUALITY DATA SUMMARIZES BASIC DATA OBTAINED FROM ANALYSES OF GROUNDWATER, COLLECTED FROM WELLS AND SPRINGS, WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL GROUNDWATER QUALITY INFORMATION FOR MANY OF THESE WELLS AND SPRINGS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF SURVEILLANCE AND FIELD STUDIES AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL.

DATE SAMP: DATE SAMPLED - MONTH AND YEAR IN WHICH WATER SAMPLE WAS COLLECTED.

PH: HYDROGEN ION CONCENTRATION - BASED ON A SCALE OF 1 THROUGH 14. WATER WITH A PH GREATER THAN 7.0 IS CONSIDERED TO BE BASIC OR ALKALINE; THE LARGER THE PH VALUE, THE MORE ALKALINE THE WATER. WATER WITH A PH LESS THAN 7.0 IS CONSIDERED TO BE ACIDIC; THE SMALLER THE PH VALUE, THE MORE ACIDIC THE WATER.

SPEC COND: SPECIFIC CONDUCTIVITY - AN INDICATOR OF THE RELATIVE AMOUNT OF DISSOLVED MINERALS IN WATER; HIGHER VALUES INDICATE GREATER AMOUNTS OF DISSOLVED MINERALS; UNIT OF MEASUREMENT IS MICROMHO

T-DIS SOLID: TOTAL DISSOLVED SOLIDS - INDICATES TOTAL AMOUNT OF DISSOLVED MINERALS IN WATER; UNIT OF MEASUREMENT IS MILLIGRAMS PER LITER

HARDNESS TOTAL: TOTAL HARDNESS - CAUSED BY THE PRESENCE OF CALCIUM, MAGNESIUM, IRON, ZINC , AND OTHER TRACE METALS. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

HARDNESS CA,MG: CALCIUM-MAGNESIUM HARDNESS - INDICATES THAT PORTION OF TOTAL HARDNESS CAUSED BY CALCIUM AND MAGNESIUM, WHICH ARE GENERALLY RESPONSIBLE FOR ALMOST ALL HARDNESS IN WATER. UNIT OF MEASURE IS MILLIGRAMS PER LITER.

THE AMOUNT OF HARDNESS IN WATER WILL AFFECT THE ABILITY OF SOAP TO LATHER OR CLEANSE BECAUSE OF THE TENDENCY OF THE IONS CAUSING HARDNESS TO REACT WITH SOAP. THE HIGHER THE HARDNESS OF WATER, THE MORE DIFFICULT IT IS FOR SOAP TO LATHER.

NOTE: TOTAL HARDNESS IS GENERALLY DETERMINED BY CHEMICAL TITRATION WHEREAS CALCIUM-MAGNESIUM HARDNESS IS GENERALLY DETERMINED BY MATHEMATICAL CALCULATION FROM CHEMICALLY-DETERMINED VALUES FOR CALCIUM AND MAGNESIUM. BECAUSE OF THIS DIFFERENCE IN DETERMINATION, THE CALCIUM-MAGNESIUM HARDNESS VALUES FOR SOME ANALYSES WILL BE LARGER THAN THE TOTAL HARDNESS VALUE.

******** PARAMETERS LISTED BELOW ARE MEASURED IN MILLIGRAMS PER LITER ********

FE: IRON	MN: MANGANESE	CA: CALCIUM
MG: MAGNESIUM	NA: SODIUM	K: POTASSIUM
HCO3: BICARBONATE	SO4: SULFATE	CL: CHLORIDE
	NO3: NITRATE (AS NO3)	

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

SWCR NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL CA.MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
4	BRYAN A BLAND	5 74	7.6	650	404	334	0.10		120.0	8.5	7.0	3.4			13.0	31.9
6	JORDAN HATCHERY #2	7 74	7.7	330	213	238			51.0	27.0	2.8	2.4			3.0	7.1
7	G HARDING	6 74	6.5	83	92	40	1.90		9.0	4.5	7.3	1.3			2.0	2.2
8	MRS ELSIE HARLEY #1	7 75	7.2	680	430	376			80.0	43.0	6.6	1.5			9.0	37.7
11	DAVID E HEATWOLE #2	6 74	7.6	470	492	290	0.20		62.0	33.0	3.0	12.8			10.0	42.5
14	IRVAN HUMMEL #1	5 74	7.5	430	398	348	0.10		120.0	12.0	10.0	6.4			22.0	14.2
16	ORIE MUMBERT	6 74	7.6	250	122	137	2.40		32.0	14.0	8.0	5.2			4.0	
21	JAMES D ECKARDT #1	6 74	7.8	240	221	147	0.10		31.0	17.0	3.0	2.5			1.0	8.9
26	JAMISON BLACK MARBLE	8 75	7.8	550	398	337	1.00	0.01	120.0	9.2	9.6	1.4			18.0	13.3
31	O W ADAMS & SONS #1	6 74	7.6	750	411	433	0.30		98.0	46.0	5.0	2.2			22.0	48.7
35	MRS J R BLOXOM	8 75	6.8	390	216	189	0.10	0.01	54.0	13.2	17.0	4.0			12.0	12.4
40	LAWRENCE E CLINE #1	6 74	7.7	270	233	161			35.0	18.0	4.0	33.0			5.0	19.5
41	RICHARD D AREHART	8 75	7.4	530	242	298			62.0	35.0	7.0	1.6			24.0	11.1
43	FIELD UNIT #8 (#1)	6 74	8.1	405	188	269	0.20		62.0	28.0	1.0	0.9			6.0	33.2
44	C J CRIDER #1	6 74	7.6	280	209	197			59.0	12.3	2.3	2.1			2.0	14.6
45	DAVID R CUPP #1	6 74	7.4	190	164	118			26.0	13.0	1.0	0.2			1.0	6.6
46	H L CUSTER #1	6 74	7.9	400	284	5	0.10		2.0	0.1	106.0	1.1				4.4
49	MRS M J DEAN #1	6 74	7.5	370	312	257	0.10		52.0	31.0	9.8	2.4			17.0	48.7
50	J A DEAN	8 75	5.9	40	3	17	0.20	0.01	4.0	1.9		1.4			3.0	0.4
52	VALLEY LEE MOTEL	7 75	7.1	880	646	985			230.0	100.0	6.4	4.0			63.0	84.6
52	VALLEY LEE MOTEL	5 74	7.4	639	457	356	0.10		120.0	14.0	40.0	2.3			31.0	53.2
54	DAYTON TRANSPORT #1	6 74	7.5	600	364	386	0.10		99.0	34.0	9.8	1.7			4.0	0.9
55	JAMES D SHULL #1	8 75	7.6	301	191	168			38.0	18.0	3.0	1.2			3.0	12.4
56	A RAY BENTCH #1	6 74	7.7	620	301	349	0.10		130.0	6.0	8.0	14.9			20.0	24.8

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
59	CHARLES G KOOGLER #2	5 74	7.6	370	257		223			76.0	8.2	10.0	3.1			7.0	23.0
62	SHEN VALLEY MEAT PROC	1 69	8.1				213	0.01		40.9	27.0	4.7	0.6	260	23.0	8.5	70.9
66	J H WENGER #1	7 75	7.4	595	366		559	0.60	0.02	160.0	39.0	13.1	0.4			10.0	19.9
66	J H WENGER #1	5 74	7.6	600	369		323			90.0	24.0	15.0	15.7			11.0	18.2
69	THE VILLAGE INN	7 74	7.5	700	374		394	0.10		107.0	31.0	10.3	0.4			23.0	8.0
70	DOUGLAS PEARCE #1	8 75	7.5	460	350		276			90.0	12.6	2.3	1.0			10.0	7.5
73	TOWN OF GROTTOES	3 73	7.9		124	121	121			30.6	10.9	0.7	2.1		4.1	0.5	1.3
84	COACHMAN INN	6 74	7.2	495	412		317	0.10		118.0	5.7	16.5	2.5			26.0	23.5
85	TOWN OF TIMBERVILLE #1	10 72	8.3		187	220	219			49.7	23.3	3.9	1.8		6.4	8.8	
86	TOWN OF ELKTON	12 65	7.1				95	0.03	0.05	29.6	5.2			150	1.4	2.5	22.6
92	BRIDGEWATER AIR PARK	7 74	7.5	345	232		223	2.40		66.0	14.2	7.0	1.3			4.0	
93	D R SHOWALTER	6 74	7.4	300	221		182			42.0	19.0	2.0				4.0	26.6
95	BROADWAY MOTEL	8 75	7.7	455	350		320			79.0	30.0		2.1			1.0	13.7
97	DONNEGAIL SUB #1	1 72	8.1		340	320	319			96.1	19.4	19.0	0.4		62.4	2.5	
98	GAILCRIST	1 72	8.1		430	330	329	0.01	0.01	76.1	34.0	1.2			21.2	22.5	
99	COUNTRYSIDE ESTATES	3 72	8.0		282	233	232	0.01	0.01	56.1	22.5	3.4	1.5		18.6	13.0	
101	VDH - COOTES STORE	6 74	7.6	215	168		113	2.90		24.0	13.0	12.0				10.0	
108	DONNAGAIL SUB #2	1 73	8.3		443	291	280	0.01	0.01	62.8	30.0	38.3	0.3		123.0	7.3	
109	MASSANUTTEN DEV CO #4	2 72	7.8				70	0.11	0.57	13.4	8.9	14.6		14	8.6	3.0	0.4
110	DONNAGAIL SUB	1 73	8.3		444	162	156	0.01	0.01	28.1	21.0	97.0	0.5		109.6	3.6	
114	ASHBY HTS #1	10 69	7.5			352	341	0.02	0.01	82.5	33.0	9.1			11.7	3.5	10.6
115	ASHBY HTS #2	10 68	8.2			487	432	0.03	0.02	101.8	55.5	36.0			22.5	32.0	14.6
116	ASHBY HTS #4	10 68	7.7			315	311	0.05	0.03	69.7	33.5	3.0			17.0	1.5	
120	TRIANGLE-F BY-PRODUCTS	6 74	7.8	600	440		350	0.10		106.0	23.0	7.3	1.1			10.0	4.9

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
121	BOND LUMBER CO	5 75	6.9	450	422		292	1.00	0.15	103.0	8.6	9.0				29.0	
122	SARCO CORP	6 74	7.4	750	649		443	0.20		165.0	7.8	16.3	1.3			51.0	31.0
123	VA DEPT OF HIGHWAYS	6 74	7.8	500	377		317	0.10		100.0	16.6	9.5	1.1			22.0	22.2
127	MERCK & CO #2	7 42	7.8				120	0.60		26.0	13.4			133	0.2	14.1	
128	BEAR LITHIA SPRING	1 68	7.9				78	0.02		18.4	7.8	8.0		90	3.0		3.5
129	MCGAHEYSVILLE SCHOOL	2 50	7.3				514	0.08		116.3	54.4			250	0.6	10.7	1.8
130	TOWN OF TIMBERVILLE SP	10 72	6.3		197	240	239		0.04	88.0	4.9	1.9	1.8		11.1	5.7	
131	TOWN OF TIMBERVILLE #2	11 72	6.2		179	199	198		0.05	57.5	13.4	1.7	1.5		5.1	5.7	
130	TOWN OF TIMBERVILLE #2	6 66	7.3				192	0.06		52.9	14.6			249	2.6	5.5	4.0
137	KAMPGROUND OF AMERICA	8 75	7.5	269	175		185			48.0	16.1		0.5			1.0	2.7
139	THE VILLAGE INN #2	7 74	7.5	700	466		416			155.0	7.2	9.0				27.0	44.3
140	NORTH RIVER STP	4 74	7.1				246	0.34	0.06	41.9	34.5	0.5			4.9	3.0	
142	DAIRYMEN SPECIALTY CO	10 73	7.5	660	368	310	305	0.03		110.0	7.6	14.0	0.9		22.0	42.0	
143	DEPT OF STATE POLICE	7 75	7.4		336		270	0.10		100.0	5.0	12.0	0.7			27.0	5.8
143	DEPT OF STATE POLICE	5 74	7.7	543	337		375	0.20		140.0	6.4	12.0	0.4			22.0	6.6
157	J H WENGER (SPRING)	7 75	7.2	561	362		310		0.02	90.0	21.0	5.4	1.8			13.0	37.7
157	J H WENGER (SPRING)	5 74	7.7	480	332		309			86.0	23.0	6.0	15.5			11.0	37.2
158	O W ADAMS	6 74	7.6	800	526		467	0.20		110.0	47.0	5.0	0.8			20.0	62.0
159	M PAUL MARTIN	7 74	7.4	460	297		260	0.60		73.0	19.1	4.3	3.0			5.0	12.4
160	DAVID E FRYE	7 74	7.1	460	352		346			78.0	37.0	7.0	2.1			7.0	4.9
161	W WILL (SPRING)	7 75	7.9	295	269		191	0.10		71.0	3.4	4.0	1.2			12.0	26.1
162	TIM TAYLOR (SPRING)	8 74	7.7	440	290		297	0.20		69.0	30.5	3.3	2.1			4.0	14.6
163	RAYMOND PRINCE	8 74	7.7	385	245		268	0.10		58.0	30.0	1.8	0.2			1.0	7.1
164	W E NEFF	7 74	7.6	460	306		276			68.0	26.0	10.0	0.3			26.0	12.4

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED! ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
169	FLEMING FARM #1	7 74	7.6	495	386		345	0.10		80.0	35.5	11.5	1.1			11.0	
171	THE VILLAGE INN #3	7 75	7.4		458		635			230.0	15.0	25.0	0.6			48.0	22.2
171	THE VILLAGE INN #3	7 74	7.4	800	490		374			140.0	6.2	23.8	1.0			48.0	24.4
173	JULIAN THOMPSON	10 74	7.7	330	190		230	0.20		78.0	8.7	5.0				8.0	21.3
182	CHARLES MONGOLD	8 75	7.7	290	193		211	0.10		81.0	2.4		0.2			2.0	4.9
183	JACK HENSLEY	5 75	7.1	310	235		207	0.10		69.0	8.6	5.2			18.0	6.0	4.9
184	ROCKINGHAM POULTRY #1	11 59	7.4				240	0.30		84.0	7.6				16.0	26.0	
185	JOHN HORST	8 74	7.7	480	324		332	0.20		73.0	36.5	1.8	1.7			1.0	2.2
186	MCGAHEYSVILLE WATER CO	8 64	7.7				184	0.15		51.0	13.8	0.7			12.8	11.0	
187	MASSANETTA SPRINGS	7 75	7.3	505	353		280			63.0	30.0	3.2	1.2			4.0	6.6
187	MASSANETTA SPRINGS	1 72	8.4		319	287	286		0.12	52.1	38.1		1.5			4.0	
190	MERCK & CO INC #4	72	8.1			88	89			21.0	9.0			98	5.0	2.0	
191	MERCK & CO INC #5	72	8.1			96	94			23.0	9.0			102	5.0	2.0	
192	MERCK & CO INC #6	72	8.1			96	94			23.0	9.0			106	5.0	2.0	
196	DAYTON (TOWN-SPRING)	5 67	7.9		1110	255	261	0.08	0.02	57.1	29.0		0.1		6.5	6.0	15.9
198	ROBERT J GORDON	8 75	7.7	485	370		260	0.10		60.0	27.0	2.0	1.2			11.0	62.0
199	GREEN VAL MED CLIN #1	5 75	6.5	130	115		72	3.70	0.33	19.0	6.0	8.9	0.2			9.0	
200	GREEN VAL MED CLIN #2	5 75	6.4	140	148		82	0.70	0.16	22.0	6.6	6.9	0.2			8.0	0.4
201	FLOYD KNICELY	5 75	7.0	350	257		197	0.10		48.0	19.0	2.4	1.3			1.0	22.2
202	CLEADUS MEADOWS JR	8 75	7.3	195	109		107	0.20		26.0	10.3		4.5			3.0	
203	SALEM CARPETS	7 75	7.2		352		529			200.0	7.3	13.4	0.5			22.0	6.2
203	SALEM CARPETS	4 74	7.4		347	334	415	0.40		140.0	16.0	3.6			5.2		
205	KERMIT EARLY	7 75	7.3		507		997			380.0	12.0	11.4	0.3			33.0	44.3
205	KERMIT EARLY	7 74	7.5	700	466		416			155.0	7.2	9.0				27.0	44.3
206	J W HONEYCUTT	5 74	7.6	700	685		427	0.10		150.0	13.0	36.0	4.9			83.0	1.3

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR ROCKINGHAM COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
207	MRS T J JENNINGS	4 74	7.4		347	376	335	0.40		85.0	30.0	11.0	0.3		25.0	30.0	
208	DAVID H LISKEY	7 74	7.6	600	403		322	0.10		118.0	6.8	13.3	0.4			29.0	17.3
208	DAVID H LISKEY	5 74	7.6	572	413		403	0.10		150.0	7.0	16.0	0.8			32.0	30.6
209	DR WILLIAM E REISH	4 74	7.4		421	322	377			140.0	6.8	50.0	0.6		25.4	42.0	0.4
210	REBEL'S ROOST MOTEL	4 74	7.6		400	20	10	0.10		3.0	0.8	21.0			16.4	13.0	
211	ROCKINGHAM MOTEL	7 75	7.7		381		3		0.02	1.0	0.2	27.0	0.1			20.0	
211	ROCKINGHAM MOTEL	5 74	7.6	659	398		438			110.0	40.0	9.3	0.4			20.0	
212	TUMBLEWEED MOTEL	5 74	7.7	550	414		354	0.10		96.0	28.0	7.0	6.6			6.0	23.5
213	VALLEY LANES INC	5 74	7.6	604	342		400			150.0	6.5	6.7	0.2			6.0	15.9
214	ROGER BARLOW #1	7 74	7.4	470	399		311	0.60		105.0	12.1	17.5	0.9			3.0	
216	CHARLES M GERRY #1	7 74	7.6	450	349		335	0.10		89.0	27.5	6.3	0.6			9.0	1.3
218	BURGESS SERVICE STA	5 74	7.8	365	384		295	22.00		110.0	5.1	12.0	7.6			27.0	
222	MT CRAWFORD RURITAN	5 74	7.7	220	141		133	0.10		52.0	0.9	7.0	2.2			5.0	21.3
224	ROCKINGHAM SLEEPWEAR	1 72	8.0		144	111	110		0.01	29.6	8.9	1.0	2.0		1.0	1.0	
226	TRINITY CHURCH	5 74	7.7	410	272		245	0.10		86.0	7.6	6.0	7.1			24.0	21.3
235	SHEN CRAZYHORSE CAMP	7 75	7.4	170	106		88			18.0	10.5	1.0	0.7			1.0	
236	RONALD DAVIS	6 75	7.3		364		244			60.0	23.0	2.4	0.7			2.0	12.4
238	HOWARD DEAN JR	7 75	6.1	33	63		14	0.10	0.04	4.0	1.1	1.4	1.4			1.0	
249	MRS HUNTER GIBBONS #1	7 75	7.8	260	202		135			36.0	11.0	3.0	2.0			1.0	15.1
260	JIM MICHAEL (H J JR)	7 75	7.4	168	104		98			22.0	10.6	1.9	2.0			1.0	
264	DON MILLER	6 75	7.4	600	453		482		0.01	170.0	14.2	9.5	1.2			18.0	8.9
265	FERN MITCHELL	6 75	7.3		265		237		0.03	64.0	19.0	5.4	1.6			7.0	12.4
266	R R RENALDS	6 75	7.9		324		270			69.0	24.0	3.7	2.5			4.0	14.2
266	R R RENALDS	10 67	7.8		255	222	217			50.5	22.2	2.1	0.3		9.2	5.0	13.3
268	PAUL SAYRE	7 75	6.7	49	36		25	0.20		8.0	1.3	1.3	1.5			1.0	

APPENDIX D

Glossary of Terms

ALLUVIUM:	A general term for sediments deposited during recent geologic time by a stream or other body of water.
ANTICLINE:	An upward fold in rock strata.
AQUICLUDE:	A geologic formation, group of formations or part of a formation which is not permeable enough to furnish an appreciable supply for a well or spring.
AQUIFER:	A geologic formation, group of formations or part of a formation capable of supplying water to wells and springs in usable quantities. An aquifer is unconfined (water table) or confined (artesian) depending on whether the groundwater level is at atmospheric pressure or greater than atmospheric pressure due to the presence of an overlying, confining geologic formation (aquiclude).
BEDDING PLANE:	The diversion plane in sedimentary or stratified rocks which separates the individual layers, beds, or strata.
BEDROCK:	Any solid rock exposed at the surface or overlain by unconsolidated materials.
CALCAREOUS:	Containing calcium carbonate.
CARBONATE ROCK:	A rock consisting chiefly of carbonate minerals such as limestone and dolomite.
CATCHMENT:	The area comprising the actual water intake area for aquifer recharge and all areas that contribute surface water to the intake area.
CLASTIC:	Consisting of fragments of rocks or of organic structures that have been transported mechanically to a place of deposition. Sandstone and shale are the most common clastics.

COLLUVIUM:	Loose soil material or rock fragments deposited by the action of gravity, usually at the base of a slope or cliff.
DIP:	The angle at which a rock bed is inclined from the horizontal.
DRAWDOWN:	The measured difference between static level and pumping level in a well; the drop in the water level due to pumping.
EVAPOTRANSPIRATION:	A term embracing that portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation, no attempt being made to distinguish the two.
FAULT:	A fracture or fracture zone along which there has been movement of two rock masses relative to one another parallel to the fracture. The movement may be a few inches or many miles, horizontal or vertical.
FLOOD PLAIN:	The strip of relatively smooth land adjacent to a river channel and built of alluvium carried by the river during floods. The flood plain is covered by water when the river is in flood.
FOLD:	A curve or bend in rock strata.
FORMATION:	A unit of geologic mapping consisting of a large stratum of some one kind of rock.
FRACTURE:	Breaks in rocks due to intense folding or faulting.
GPD:	Gallons per day.
GROUNDWATER:	Water below the water table; water in the zone of saturation.
HYDROLOGY:	The science that relates to the water of the earth.
IGNEOUS:	Rocks or minerals that solidified from molten rock (magma).
IMPERMEABLE:	Having a texture which does not allow perceptible movement of water through rock.

INTRUSIVE:	Refers to igneous rocks which have penetrated into or between older rocks while molten but have solidified before reaching the surface.
JOINT:	A fracture in rock along which no appreciable movement has occurred. Joints are generally perpendicular to bedding planes.
KARST TOPOGRAPHY:	Topography characterized by sinking streams, sinkholes, caves and similar features indicative of underground drainage developed through the solution of bedrock.
LITHOLOGY:	The composition and structure of rock.
METAMORPHIC:	Refers to any rocks derived from pre-existing rocks in response to pronounced changes of temperature, pressure and chemical environment.
MGD:	Million gallons per day.
PERCOLATION:	Movement of water through the interstices of rocks or soils except movement through large openings such as solution channels.
PERMEABILITY:	The ability of a rock, sediment or soil to transmit water.
POROSITY:	The property of a rock, soil, or other material of containing spaces or voids.
PUBLIC SUPPLY:	As defined by the Virginia Department of Health, a water system serving 25 individuals or more than 15 residential connections.
PUMPING LEVEL:	Depth to water in a well when the well is being pumped.
RECHARGE:	The addition of water to an aquifer by natural infiltration or artificial means.
RUNOFF:	That part of precipitation that appears in surface streams. Groundwater recharge is that part of runoff which has existed as groundwater since its last precipitation.
SEDIMENT:	Material borne and deposited by water.
SEDIMENTARY:	Refers to rocks formed from the consolidation of layered sediments that have accumulated in water.

SINKHOLE: A funnel-shaped depression in the land surface, usually in limestone regions, developed by the dissolving action of water and connected with solution channels underlying the depression.

SOLUTION CHANNEL: Joints or fractures in carbonate rocks which have been enlarged by the dissolving action of water and which are capable of transmitting large quantities of water.

STATIC LEVEL: Depth to water in a well when the well is not being pumped.

SYNCLINE: A downward fold in rock strata.

TERRACE: A level or gently inclined surface bordering a stream which represents a former level of the stream. Terraces are composed of alluvium produced by renewed downcutting of the flood plain or valley floor by the stream.

UNCONSOLIDATED: A sediment that is loosely arranged or unstratified, or whose particles are not cemented together.

WATER TABLE: The upper surface of the zone of rock or soil saturated with groundwater.

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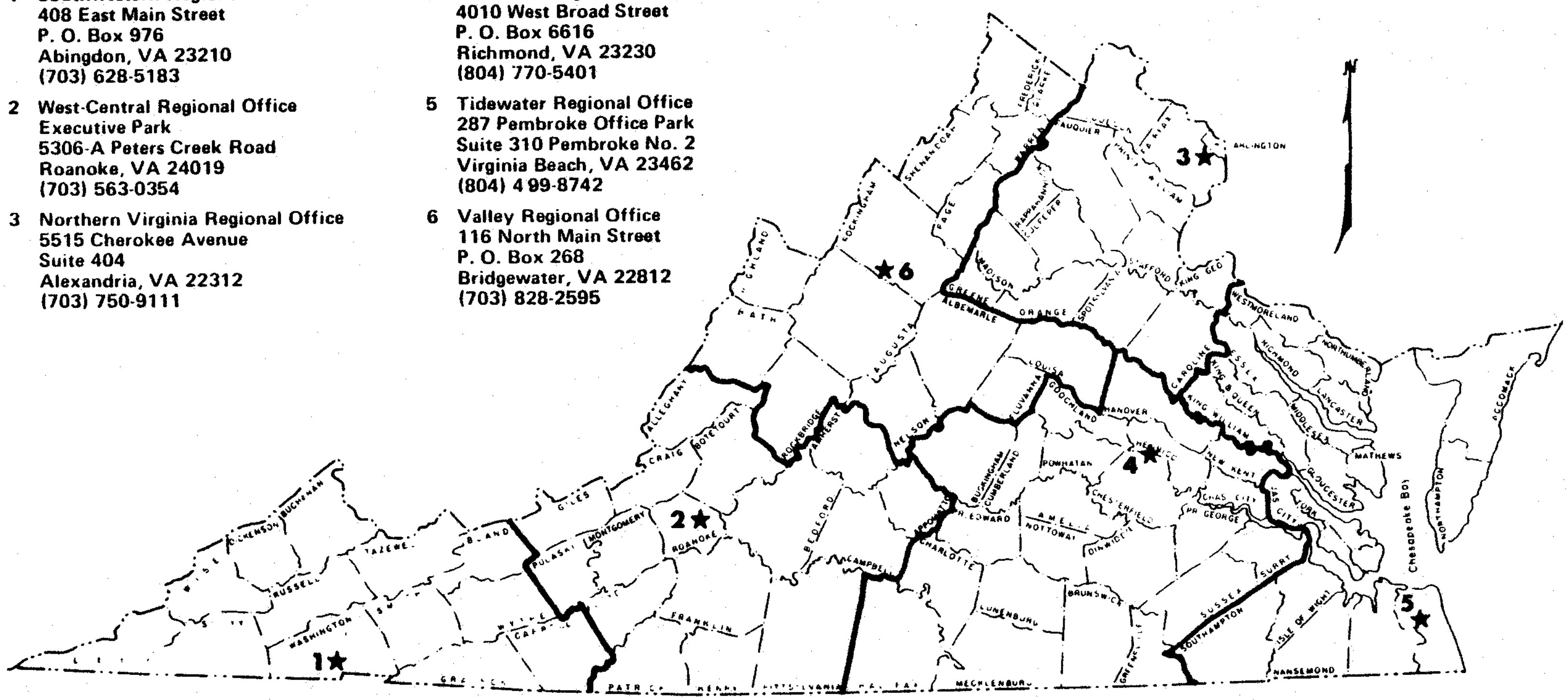

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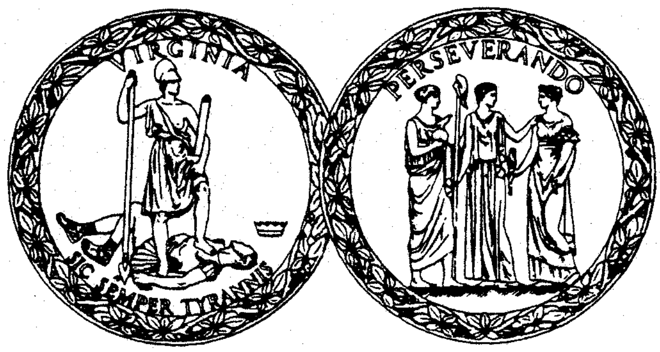
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